UNIVERSITY COLLEGE OF WALES

ABERYSTWYTH

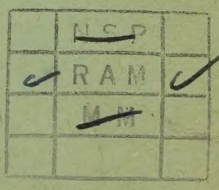
REPORT

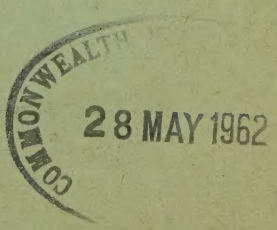
OF THE

WELSH PLANT BREEDING STATION

FOR

1961





Sheep grazing S. 341 cocksfoot early March 1961.

WELSH PLANT BREEDING STATION
ABERYSTWYTH

REPORT

FOR

1961

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DIRECTOR'S REPORT

Staff

Mr. A. R. Beddows, M.Sc., F.L.S., who was in Grass Breeding for 37 years, and Mr. Gwilym Evans, O.B.E., M.Sc., who was in charge of Seed Multiplication for 32 years, and latterly Deputy Director, retired on 30 September 1961. Mr. Tom Owen, for more than 36 years on the farm staff, also retired on 30 September. We extend our best wishes to our colleagues.

Dr. D. J. Griffiths has been appointed Deputy Director and to be in charge of Herbage Seed Research; Mr. J. D. Hayes to be head of the Cereals, Beans and *Brassicae* work, and Dr. E. L. Breese to be head of Grass Breeding. Mr. Roy Hughes, M.Sc., and Mr. James M. M. Munro, B.Sc., were appointed to Grassland Agronomy, and Mr. P. L. Catherall, B.Sc., to Plant Pathology. Mr. W. T. H. Peregrine, M.Sc., Experimental Officer in Cereals, Beans and *Brassicae* Breeding, resigned to take up the position of Plant Pathologist in Tanganyika.

We congratulate Mr. Rhys M. Williams, Foreman at Frongoch Farm, who has been on the staff of the Station since its commencement in 1919, on being awarded the Royal Welsh Agricultural Society's Long Service Medal which was presented by the President of the Society, Sir Grismond P. Philipps, C.V.O., Lord Lieutenant of Carmarthenshire, at the Royal Welsh Show, Gelli Aur, Llandeilo, 25 July 1961.

We are also pleased to record the honour to Emeritus Professor T. J. Jenkin, C.B.E., D.Sc., on being awarded the Diploma of Honorary Membership of the Swedish Seed Association.

Mr. A. H. Charles, Mr. J. L. Stoddart and Mr. Hugh Thomas were awarded the Ph.D. degree of the University of Wales.

The Director was invited by the United States Department of Agriculture to visit herbage seed producing areas in Oregon, Washington and Idaho. Experiments are in progress to study genetic shift in Aberystwyth varieties after they have been reproduced in the United States.

The Director and Mr. D. G. Miles were members of the British Grassland Society delegation which visited typical grassland areas, upland and lowland pastures and research stations in south-west France at the invitation of the Association Francais pour la Production Fourragère.

The following members of staff were awarded travel grants by the Agricultural Research Council:

Dr. E. L. Breese to attend a Symposium on Statistical Genetics and Plant Breeding at North Carolina, U.S.A., and to visit research institutions in the United States and Canada.

Mr. Roy Hughes, Dr. Martin Borrill, Mr. Ieuan Davies and Mr. J. D. Hayes to visit Portugal, north-west Spain, the Pyrénées and south-west France to collect indigenous plant material for use in the grass and cereal breeding programmes.

Visiting research workers

Dr. John Cotten, Univ. Durham, who was awarded a post-doctoral I.C.I. Research Fellowship, is attached to the Department of Agricultural Botany, and is working on resistance in cereals to the cereal root-eelworm (*Heterodera avenae*) in the Cereals, Beans and *Brassicae* section.

Mr. J. Sithamparanathan, a British Council Scholar from Ceylon, and Mr. D. M. Calder, M.Sc., Massey Agricultural College, Palmerston North, New Zealand, are continuing their post-graduate studies.

Mr. Magnus Oskarsson, Iceland, and Mr. Ahmed Kheiralla, Sudan, spent some months at the Station studying methods and techniques.

Post-graduate students

Mr. K. J. R. Edwards, Univ. Reading, was awarded the Ph.D. degree of the University of Wales and has taken up a post-doctoral Fellowship in Genetics at the University of California, U.S.A. Mr. L. Beevers was also awarded the Ph.D. degree and has taken up a post-doctoral Fellowship in Plant Physiology at the University of Illinois.

Mr. P. J. Randall, B.Sc., an A.R.C. Research Scholar, commenced work on the 'Genetic control of response to aluminium and manganese in herbage grasses'.

Visitors

The Station was again pleased to welcome numerous visitors from Great Britain and overseas, including Lord Brecon, J.P., Minister of State for Welsh Affairs, and Lord Craigton, Minister of State, Scottish Office.

Amongst the organised parties we received members of the Private Plant Breeders' Association, the Society of Experimental

Biology, the Aberystwyth Seeds Committee, the Welsh Black Cattle Society Annual Field Day at Morfa Mawr, and the N.A.A.S. Also students from the University College of Wales, Aberystwyth, University College of North Wales, Bangor, University of Manchester, from the Colonies, and from Derby and Stafford Training Colleges and Glynllifon Farm Institute. A large number of students from universities and schools in this country, also from Austria, France, Greece, Nigeria and Switzerland assisted during the summer.

Seminars were given at the Station by visiting scientists: Professor J. E. Grafius, Michigan State University; Professor G. L. Stebbins and Professor R. W. Allard, University of California, Dr. R. F. Williams, C.S.I.R.O., Canberra, Australia, and Dr. N. W. Simmonds, John Innes Horticultural Institution.

Conferences and Lectures

The Director took part in technical meetings in Rome on Plant Exploration and Introduction at the request of the Food and Agriculture Organisation of the United Nations.

Dr. Alice M. Evans attended a Symposium on Fertility in Tetraploid Clovers organized by the Fodder Crops Section of Eucarpia at the Swedish Seed Association, Svalöf, at which she gave a paper on 'Embryo/endosperm relationships in polyploid clovers'.

The Director and Dr. J. P. Cooper provided an exhibit at the Royal Society Conversazione in London on the theme 'Reproductive unbalance as a consequence of selection in ryegrass'.

At the Winter Meeting of the Genetical Society Dr. J. P. Cooper read a paper on 'Changes in fertility and vigour associated with selection for ear emergence in *Lolium*', and Mr. J. D. Hayes on 'A latent gene controlling Ddt sensitivity in *Hordeum*'. At the Spring Meeting Dr. K. J. R. Edwards and Dr. J. P. Cooper gave a joint paper on 'The genetic control of leaf development in ryegrass'. At the Summer Meeting Mr. A. R. Beddows and Dr. J. P. Cooper staged a demonstration on 'A genetic dwarf in ryegrass and its modification by gibberellic acid', and Mr. W. Ellis Davies demonstrated 'Leaf markings—examples of allelic series in white clover (*Trifolium repens* L.)'.

Dr. D. J. Griffiths gave a paper on 'Breeding for resistance to crown rust in the oat crop' at the Symposium on The Cereal Rusts arranged by the British Mycological Society.

Mr. T. D. Johnston gave a paper on 'Studies on the use of radiation in oat breeding' to the Association of Applied Biologists.

At the Summer Meeting of the Society for Experimental Biology joint papers were given by Dr. J. P. Cooper and Miss M. A. Ford on 'Leaf size and cell pattern in *Lolium*'; by Mr. P. B. Vose and Mr. D. Gareth Jones on 'The interaction of calcium and manganese on nodulation and growth in varieties of *Trifolium repens* L', and by Mr. P. J. Randall and Mr. P. B. Vose on 'The effect of aluminium on the short-term uptake of stable radioactive phosphorus in *Lolium perenne*'. At the Amsterdam meeting Dr. D. J. Griffiths and Mr. P. B. Vose gave a joint paper on 'Varietal differences in the manganese and magnesium nutrition of oats'.

Dr. Martin Borrill gave a paper to the Linnean Society Symposium on Experimental Taxonomy entitled 'The genetic aspects of species relationships in *Anthoxanthum*'.

Mr. W. T. H. Peregrine read a paper to the N.A.A.S. Discussion Group on Frit Fly Problems entitled 'New sources of frit fly resistance'.

The Station participated in two specialist conferences at the Agricultural Research Council in London. The first on the Management of Hill Sheep in Wales, attended by the Director and Mr. Roy Hughes, and the second on Nitrogen in Hill Pastures, attended by the Director, Mr. Vose and Mr. Gareth Jones.

The Refresher Course for ~~Cereal~~ Seed Crop Inspectors organized jointly by N.I.A.B./W.P.B.S., was held at the Station this year to mark the coming of age of the Herbage Seed Crop Certification Scheme. Mr. E. C. Large, Ministry of Agriculture Plant Pathology Laboratory, addressed the inspectors on the joint W.P.B.S./N.A.A.S. white clover phyllody survey.

The usual Refresher Course for Cereal Seed Crop Inspectors was held, and a three-day course was again given at the request of the Institute of Corn and Agricultural Merchants.

To mark World Seed Year a joint N.A.A.S./W.P.B.S. Conference was held on the theme 'Better Seeds—Better Crops', attended by 100 participants.

Developments in research

A prominent industrialist recently described agriculture as a simple extracting industry like mining. This naïve concept has been

responsible for disastrous exploitation of land over many parts of the world, resulting in unproductive prairies and even deserts.

Agriculture must be considered in terms of highly complex biological synthetic processes, involving the living soil and the efficient conversion of raw materials by crops into the types of fodder required by animals for maximum production.

Plant Breeding plays an important role through the development of improved varieties for the vital intermediate link between the soil and the animal. Of the many factors which the breeder has to consider, the reaction of plants to light and temperature is of great importance. For example, Cooper (p. 16) finds that the efficiency with which a grass plant can grow at low temperature depends on its climatic origin. Cocksfoot and ryegrass of Mediterranean origin possess a greater ability to grow actively at lower temperatures than those from Northern Europe, but this material is less resistant to frost damage than the more winter-dormant northern types. On the other hand, plant material of northern origin shows a greater response to increasing light intensity in the spring.

For maximum light interception the growth habit of the plant is also important, as is shown in experiments described by Miss Alison Davies (p. 86).

Recent work by Troughton (p. 89) has shown that the ratio of shoot to root in a grass plant may be important for the breeder, since it can influence not only the efficiency of the extraction of water and nutrients from the soil, but also the response to cutting and/or grazing.

The efficient uptake and utilization of fertilizers by the plant are important considerations for herbage production. Vose and Breese (p. 25) find that individual genotypes even within a single ryegrass variety differ markedly in their ability to take up and use nitrogen.

The development of laboratory techniques for assessing the nutritive value of single genotypes has made it possible to select breeding material for such constituents as digestibility, soluble carbohydrate and protein content (Cooper, p. 145, Jones p. 157). For the first time, therefore, we can look forward to varieties of grass in which equal consideration is given to their gross yield and feeding value for the animal.

In the synthesis of new varieties the breeder must take advantage of all possible sources of plant material. Populations from old established pastures prove to be a useful source of variation for the immediate improvement of pasture varieties (Breese, p. 30). When unusual characteristics are required, material from more widely dispersed habitats will be valuable, and for this purpose extensive collections, particularly from the Iberian Peninsula (p. 137) and North Africa (p. 110) have recently been obtained.

Crosses between North African tall fescues and our indigenous form of this species S.170, show promise for the production of varieties with different growth rhythms, and also for incorporating some of the best characteristics of both types. With the same object in view fertile derivatives have been obtained between Italian ryegrass and tall fescue. These have reached a stage for selection of desirable types (Lewis, p. 34).

The above basic studies on individual plants are complementary to those on varieties grown under competitive conditions in swards. Clovers are important companion species to grasses, and in mixtures high production can be achieved without unusually heavy applications of nitrogenous fertilizers. For example, Miles (p. 76) obtained 5 tons of hay (11% moisture) per acre in early June from a mixture of timothy S.352 with red clover.

In general the breeder is at a disadvantage unless there is a full assessment of plant material in swards and under a variety of conditions. A study of sward behaviour in relation to different edaphic and climatic conditions provides useful guidance to the breeder, since, as pointed out by Dr. Richard Phillips (p. 165), animal production is closely correlated with these factors.

For these reasons increasing attention is being given to environmental factors which influence the agronomic behaviour of different species, varieties and specific genotypes. Little attention has hitherto been given to the precise characterization of the environment, particularly on hill land areas. Hughes (p. 80) is developing a research programme to study the significant factors of plant performance relevant to reseeding in hill areas. The aim is to ascertain whether the environmental limits prevailing in the hills could be better exploited by specially-bred varieties, and if so, to set about factually describing models for the breeders. Throughout this phase emphasis is being placed on the reaction of plant material in swards to microclimate in addition to interactions with contrasting soil types. Initially special attention will be given to

the behaviour of plants during the temperatures that prevail in late winter and early spring.

The problem of flowering and seed production in herbage plants

In breeding herbage plants for superior vegetative characters difficulties can arise in the production of seed at an economic price. Hitherto a compromise has been accepted between leafiness and high agronomic performance on the one hand, and high seed potential on the other. For satisfactory seed production even in these varieties special attention must be given to cultural conditions and management (e.g. Lewis, p. 129).

Time of harvesting for maximum yield of seed is also very critical and Stoddart (p. 98) has attempted to define in chemical and physical terms the exact state of seed ripeness. He finds that prior warning of 3-4 days can be given of imminent ripeness from a determination of soluble carbohydrate content.

Another approach to the problem of seed production is through the possible artificial induction of flowering on a field scale. Success has been achieved in the induction of flowering and seed production in normally completely vegetative genotypes of red clover by the application of gibberellin (Stoddart, p. 119). From the results obtained there is no reason why this technique can not be applied successfully on a field scale. Work is also proceeding on the development of similar techniques for grasses where the problem of flowering is found to be more complex.

New varieties

The following new varieties are now in process of seed multiplication for distribution to the Trade:

Grasses

S.321 perennial ryegrass. A good all-round grazing variety which remains particularly winter green.

S.341 cocksfoot. Specifically bred for early spring growth.

S.352 timothy. A leafy rust-resistant variety which gives outstanding production during May and June.

Oats

Maelor (S.236). A special-purpose spring oat which combines high quality grain with good straw production.

Padarn (S.237). A high yielding mildew-resistant winter variety.

Extra-mural collaboration

The Plant Breeding Division of the Ministry of Agriculture, Northern Ireland, and the Grass Breeding Section are collaborating in a programme designed to introduce resistance to blind seed disease into S.24 perennial ryegrass. Basic plants of this material have been supplied to Loughgall where they have been crossed with resistant material developed in Northern Ireland. Members of both departments will co-operate in selecting resisters of appropriate agrotype from the progeny of these crosses, and of subsequent backcrosses to S.24.

The Station is participating in the Tetraploid Red Clover Project organized by the Fodder Crops Section of Eucarpia with clover breeders from ten European breeding stations who will exchange breeding material and co-operate in running trials. The first joint project consists of mixing the seed of populations of tetraploid red clover from the ten stations and distributing a sample of the mixture to all contributors for multiplication and selection under the environmental conditions of each location. The aim is to increase the gene pool of tetraploids, and by recombination of genes to produce more desirable types.

As a guest research worker at the Institute of Biological and Chemical Research on Field Crops and Herbage at Wageningen, Miss Alison Davies has been working in association with Dr. Alberda in a study of factors influencing the rate of regrowth in contrasting types of perennial ryegrass. We wish to thank the Director, Professor G. J. Vervelde, and members of his staff for their kind co-operation.

Dr. K. B. Sinclair, M.R.C.V.S., Department of Agriculture (Animal Health), U.C.W., Aberystwyth, is collaborating on problems which relate to the possible toxicity of herbage containing high nitrate content. We also wish to thank him for fitting rumen cannulae in sheep for our work on the *in vitro* digestibility of various grass varieties.

Dr. R. K. Pfeiffer, Chesterford Park Research Station, is collaborating with the cereal breeders in the selection of barley for resistance to selective herbicides.

Acknowledgements

We wish to express our appreciation to:

Mr. W. F. Raymond and Dr. J. M. A. Tilley, Grassland Research Institute, Hurley, for carrying out analyses of *in vitro* digest-

ibility on genetical material of perennial ryegrass and cocksfoot, and so making possible selection for high digestibility.

Dr. P. W. Brian, F.R.S., Head of Pharmaceuticals Division of I.C.I. Akers Research Laboratories at Welwyn, who has generously provided supplies of eight of the nine known gibberellins for trials to assess their florigenic activity when applied to non-flowering herbage varieties developed at this Station.

Professor D. B. Vitória Pires, Director of the research stations at Elvas and Sacavém, for his valuable help in connection with the plant collections in Portugal, and also to Dr. J. Malato-Beliz and Dr. A. Teles for their help as guides and interpreters.

Mr. N. C. Keulemans and Mr. M. Thiault, F.A.O., for collecting 22 lots of tall fescue from widely different habitats in Tunisia, and to Mr. Van der Sprenkel for providing useful climatological data on the areas in which the tall fescue was growing.

Professor P. F. Wareing and Mr. B. S. O. Fox, Department of Botany, U.C.W., Aberystwyth and Mr. R. Peake, N.A.A.S. (Wales), Trawscoed, for assistance in replanting the woodlands and laying out the grounds of the Gogerddan Estate.

Mr. W. H. Hogg, Senior Meteorological Officer, N.A.A.S., Bristol, for helpful advice.

We wish to thank the numerous firms, organizations and individuals who have supplied seeds, plants, chemicals and insecticides for experimental purposes.

We are glad to place on record our appreciation of the collaboration of the staffs of the National Agricultural Advisory Service; the National Institute of Agricultural Botany; the Forestry Commission; the Hill Farming Research Organisation, Edinburgh; The Grassland Research Institute, Hurley; The Royal Botanic Gardens, Kew, and the Institute of Rural Science, U.C.W., Aberystwyth.

We are grateful to the following who have generously provided land facilities for special experiments: Capt. G. L. Bennett Evans, O.B.E., M.Sc., Manod, Llangurig; Mr. H. E. Williams, Bwlch Crwys, Devil's Bridge; the N.A.A.S. (Wales) Experimental Husbandry Farm, Pwllpeiran; Mr. Dan Davies, Lletty Ifan Hen, Bontgoch; Mr. W. Morgan, Tynrhyd, Devil's Bridge; Mr. W. T. K. Raw-Rees, Brynbwl, Borth; Mr. D. Rogers, Bacheldre, Churchstoke, and the Rt. Hon. Lord Rennell of Rodd, K.B.E., C.B., D.L., The Rod, Presteign, Radnorshire.

Special thanks are again due to Miss Irene D. Rees for her painstaking work in compiling this report and for seeing it through the press.

DEVELOPMENTAL GENETICS

J. P. Cooper

The aim of the research programme is to study the genetic and physiological basis of those characters which are important to the breeder and the agronomist, and to explore the possibilities of selection for their optimum expression.

The topics under investigation include developmental responses to light and temperature for germination, vegetative growth and flowering (J.P.C.), nutrient uptake and assimilation (P.B.V.) and the possibility of selection for nutritive value, in collaboration with Chemistry and Grass Breeding (p. 145).

Light and temperature responses for vegetative growth (J.P.C., M.A.F., R.L.T.)

In view of the importance of seasonal productivity in Britain, particularly during late autumn and early spring, a survey has been started of the growth pattern of climatic races of herbage grasses under different light and temperature regimes, and the possibility of selection for production at low temperatures and low light intensities.

Screening of seedling material over a range of temperatures has revealed marked differences between populations in their ability to grow at low temperature (5°C.), these differences being related to the region of origin. In perennial ryegrass, increase in leaf area at 5°C. is greatest in the Mediterranean populations, followed by the New Zealand and Irish material, with least growth in the Danish and Russian samples. Cocksfoot shows a similar picture, with highest production in the south European and Mediterranean samples; continental material is lower, and a Norwegian population from near the Arctic Circle least of all. Survival of freezing temperatures (–5°C. for 3 days), however, shows the reverse order, the Mediterranean populations being killed completely, and the continental material, such as the north Norwegian cocksfoot, giving the greatest survival. The ability to make active growth at moderately low temperatures is thus inversely correlated with frost survival.

These differential temperature responses are confirmed by glasshouse sowings throughout the year, with the Mediterranean

populations giving the highest relative dry matter production in the winter. This glasshouse picture is complicated, however, by differential response to light energy: the north European material responds much more to increased light intensity than does the Mediterranean.

Temperature responses in climatic races of ryegrass and cocksfoot

Varieties	*Relative increase in leaf area at 5°C.*	*Per cent survival after freezing at –5°C.*
Ryegrass		
Algiers	26.6	0
New Zealand	13.8	20
Irish	12.2	47
Devon	11.1	36
Melle	9.5	57
S.23	9.2	33
Pajbjerg	7.6	73
Russian	7.7	92
Cocksfoot		
Bordeaux	29.4	0
Israel	27.9	0
Portugal	24.2	0
S.143	25.5	0
Danish	16.4	14
Russian	16.4	33
Norwegian	9.3	88

The temperature responses for germination are also under study in a range of ryegrass populations. The greatest tolerance to high temperature stress (35°C.) has been found in *Lolium rigidum* from desert areas in the Middle East, and that to low temperature (5°C.) in continental varieties of *Lolium westerwoldicum*.

Considerable variation occurs within these local populations under all light and temperature regimes, and parents have been selected from three contrasting ryegrass varieties for high germination and rapid increase in leaf area at high, optimum and low temperatures.

Selection for leaf and tiller development (J.P.C., K.J.R.E.)

Response to selection for leaf size and rate of leaf appearance in Italian and perennial ryegrass has continued in the fourth generation, and by now most of the selection lines are well outside the original varietal ranges:

Selection for leaf size in ryegrass : Fourth generation

		Leaf size (mm^2)	*Per cent realised herit-ability*	*Seed weight* (*mgm./ 100 seeds*)	*Dry weight per*	
					Plant (*gm.*)	*Tiller* (*mgm.*)
Italian	High	1745	31	304	0.70	63
	Original	1069	26	227	0.56	34
	Low	742		216	0.51	32
Irish	High	934	39	258	0.74	46
	Original	611	46	205	0.64	38
	Low	182		150	0.27	23
L.S.D at 5%			—	17	0.15	13

In most lines the changes in leaf size are based on changes in cell number, though in the Irish low line, cell size was also reduced. Both cell size and number show heritabilities (in the broad sense) of about 70%. Examination of the 4th generation lines has revealed a strong positive correlated response between leaf size and seed weight ($r = 0.85$), which appears to be based primarily on differences in embryo size.

While extensive response in these individual components of total leaf area has been obtained there has been no regular increase in total dry weight over the original varieties. Selection has evidently been concerned more with the redistribution of material than with increased production of dry matter. Attention has therefore shifted to differences in the accumulation of total leaf area, and in photosynthetic efficiency, as measured by growth analysis. Preliminary results show little difference in the relative growth rate or net assimilation rate of Italian and perennial ryegrass in the early seedling stage, although Italian is greatly superior in dry matter production. This suggests that differences at or soon after germination are operating, and an effect of seed weight on early seedling vigour may be implicated. Selection for seed weight has, therefore, been started in Italian and perennial ryegrass. Correlated changes in leaf size, but not in tiller number or rate of leaf appearance, have been recorded in the initial material, but these cannot as yet be separated into genetic and environmental components.

Selection in a simulated sward (J.P.C.)

Earlier studies have dealt with the performance of young seedlings grown in boxes without competition, but in practice a herbage variety is grown in the field in a highly competitive sward. The possibilities of selecting parents for production under controlled competition and defoliation are therefore being studied.

During 1958-59 a number of varieties of Italian and perennial ryegrass were grown in a simulated sward at $1\frac{1}{2}''$ spacing, and cut regularly at ground level and at a height of 2″. In autumn 1959 the weakest and the most vigorous surviving plants from each treatment were selected for crossing, and their progenies have been sown out in spring 1961 in a similar simulated sward.

The first cut on these progenies taken in August showed marked differences in dry matter production between Italian and perennial ryegrass, between families within each variety and also between the ground level and the 2″ cut. By the third cut in October 1961, however, there was no difference between the two levels of cutting, and few significant family differences. In both parent and progeny material there was little correlation between production at the first cut, composed largely of undisturbed seedling growth, and regrowth in the third cut, after competition and defoliation had been operating for some time. Studies on early seedling growth may, therefore, bear little relation to production in a competitive sward.

The assessment of optimum leaf area index (J.P.C.)

While a rapid rate of increase in leaf area is important in the seedling stage or after defoliation, a high optimum leaf area index is also desirable to make the most effective use of incoming light. A series of growth analyses have therefore been started to measure the optimum leaf area index at different seasons, and to see whether varietal or family differences can be detected for this character.

Pilot analyses in which differences in leaf area were obtained by altering the density of sowing showed that relative growth rate and net assimilation rate decreased regularly with an increase in leaf area. The density dependence of these components followed the same curve in both Italian and Irish perennial ryegrass, though leaf area increased more rapidly in Italian. The curves relating crop growth to leaf area index were similar for both varieties, with Italian showing an optimum leaf area index of 6 to 7. By the end

of the experiment, Irish perennial ryegrass had reached a value of 5, which was still below the optimum. This technique can evidently be used to determine the optimum leaf area index of contrasting herbage varieties under different light and temperature regimes.

Flowering responses in herbage grasses (J.P.C., D.M.C.)

Earlier work on flowering responses in *Lolium* had shown this genus to follow a similar pattern to that of the spring and winter cereals. The perennial species possess an absolute requirement for cold or short day induction, the annuals have little or no requirement, and the biennials are intermediate. Not all perennial grasses, however, behave in this way. Timothy (*Phleum pratense*) appears to have no inductive requirement for cold or short day, while in cocksfoot (*Dactylis glomerata*) it has not been possible to bring about floral induction by either cold or short day treatment given to the young seedling.

A survey of inductive and post-inductive requirements has therefore been started in a range of annual, biennial and perennial grasses from different climatic origins. In order to discover their inductive requirements young seedlings were given 0, 6 and 12 weeks of cold (3–4°C.) or short-day (8 hrs.), and then transferred to continuous light in a warm glasshouse. The pattern of inductive response is shown on p. 21.

The summer annuals, such as *Lolium westerwoldicum* and *Phalaris minor*, headed rapidly in all treatments, while the winter annuals, including *Bromus secalinus* and *Alopecurus agrestis*, showed either a quantitative response to induction, or a proportion of non-flowering plants in the control.

The biennial and perennial species exhibited a wide range of responses; some, such as *Ceratochloa unioloides* and *Poa nemoralis*, headed rapidly without any induction, while there was a large group, including *Phalaris tuberosa*, *Phleum pratense* and *Arrhenatherum elatius* which showed an irregular proportion of heading plants bearing no relation to the length of the inductive period. These species all form long stoloniferous or rhizomatous shoots when grown under continuous light in the glasshouse.

Definite inductive response to cold or short-day is shown by a comparatively small group of biennials and perennials. Some, such as *Lolium multiflorum*, *L. perenne* and *Trisetum flavescens*,

Inductive responses in annual and perennial grasses
(per cent heading)

Species	Control	Cold		Short day	
		6 *wks.*	12 *wks.*	6 *wks.*	12 *wks.*
Annuals					
Lolium westerwoldicum	100	100	100	100	100
Phalaris minor	100	100	100	100	100
Bromus secalinus	100*	100	100	100	100
Lagurus ovatus	100*	100	100	100	100
Hordeum marinum	85	100	100	100	100
Alopecurus agrestis	80	85	100	90	100
Perennials					
Ceratochloa unioloides	100	100	100	100	100
Poa nemoralis	100	100	100	100	100
Phalaris tuberosa	90	100	100	100	100
Phleum pratense	65	65	60	50	85
Arrhenatherum elatius	5	20	25	26	25
Poa palustris	58	100	100	100	100
Lolium italicum	50	85	100	35	100
L. perenne	5	30	100	45	55
Trisetum flavescens	0	0	100	10	60
Agrostis tenuis	0	0	10	45	65
A. alba	0	0	0	5	65
A. stolonifera	0	0	0	0	55
A. canina	0	0	0	0	35
Bromus erectus	0	0	0	0	29
Anthoxanthum odoratum	0	0	0	0	0
Brachypodium pinnatum	0	0	0	0	0
Cynosurus cristatus	0	0	0	0	0
Dactylis glomerata	0	0	0	0	0
Festuca ovina	0	0	0	0	0
F. pratensis	0	0	0	0	0
F. rubra	0	0	0	0	0
Holcus lanatus	0	0	0	0	0
Phalaris arundinacea	0	0	0	0	0
Poa pratensis	0	0	0	0	0

*Quantitative response to induction.

respond more to cold induction, while others, including many species of *Agrostis*, respond mainly, or solely, to short day.

The great majority of the perennials, however, remain completely vegetative even after 12 weeks' cold or short day. This group includes such species as *Dactylis glomerata*, *Cynosurus cristatus* and *Poa pratensis*, which have been reported to respond to winter induction in the mature plant stage. Evidently the species in this group either:

(a) require a longer inductive exposure than 12 weeks,

(b) have a juvenile stage, during which they cannot respond to inductive treatments, or

(c) are inhibited by continuous light compared to long day in the post-inductive stage.

Flowering responses in *Dactylis* (D.M.C.)

Most cocksfoot varieties remain completely vegetative on transfer to continuous light after 12 weeks' seedling induction by cold or short day, yet when sown outdoors in the spring (April–May) many plants, even from north European varieties, produce heads freely without having been exposed either to cold or short day.

The inductive requirements of two contrasting climatic varieties, a Mediterranean sample from Palestine and the British S.143, are therefore being studied. In 1960 nearly all plants of the Palestine variety headed after sowing on 29 April, while the S.143 gave only 37% heading under this treatment. In 1961 these varieties were sown outdoors early in April, some plants were grown throughout in either continuous light, short day (8 hrs.) or natural long day, while others were given 3, 6 or 12 weeks' short day or continuous light before transfer to natural long day.

Initiation and elongation of heads occurred in most plants of both varieties grown in natural long days. There was a slight accelerating effect of short-day induction, but both continuous light and short day throughout prevented ear emergence in all plants, though a few heads were initiated in the Palestine variety.

It is suggested, therefore, that there exists a dark requirement for floral induction which can be satisfied by either long or short days, but this must be followed by long days for subsequent elongation of the inflorescence. In S.143 post-inductive continuous light is evidently inhibitory compared with long days. Dissection of field material has shown that floral initiation can occur in many varieties in the short days of winter, but that ear elongation does not occur until the longer days of early spring.

Flowering responses in cocksfoot

	Palestine			*S.143*		
	Per cent heads		*Days to 50% heading*	*Per cent heads*		*Days to 50% heading*
	Emerged	*Initiated*		*Emerged*	*Initiated*	
Natural long day throughout	80	0	84	60	0	115
3 wks. CL→LD	100	—	88	10	20	—
6 wks. CL→LD	100	—	83	0	20	—
12 wks. CL→LD	33	33	—	0	10	—
Continuous light throughout	0	30	—	0	0	—
3 wks. SD→LD	80	10	79	44	0	—
6 wks. SD→LD	100	—	71	70	0	82
12 wks. SD→LD	100	—	107	30	20	—
Short day (8 hrs.) throughout	0	20	—	0	0	—
21 wks. SD→CL	100	—	not recorded	0	0	not recorded

The use of leaf number as a criterion of heading (D.M.C.)

Leaf number (or node number) before heading has often been used as a quantitative measure of the rapidity of heading, but it is usually not clear whether this is simply a convenient time scale or has some intrinsic developmental significance.

The lines of perennial ryegrass selected for rapid and slow rate of leaf appearance have provided useful material for distinguishing between these two alternatives. Seeds of rapid and slow lines of Irish and Hunsballe ryegrass were fully induced by 20 weeks' cold treatment, and then grown in continuous light. The speed of reproductive development was measured by days to ear emergence and also by leaf number before heading.

Heading response in selection lines of ryegrass

	Days to heading	*Leaf No. before heading*	*No. of spikelets*	*Rate of leaf appearance (leaf/day)*
Irish fast	31.1	8.3	7.1	0.283
Irish slow	31.4	6.2	8.6	0.217
Hunsballe fast	31.2	8.0	11.1	0.238
Hunsballe slow	31.4	6.7	15.1	0.208
L.S.D. at 5%	2.2	0.43	0.94	0.03

The time to ear emergence was the same in both rapid and slow selection lines, but leaf number before heading was much higher in the rapid lines. Spikelet number, on the other hand, was lower in the rapid selection lines, suggesting that selection has operated mainly on the rate of leaf expansion rather than on the rate of initiation of leaf primordia.

These results suggest that leaf number before heading simply provides a convenient time scale, and that its use for comparing heading responses in different species and varieties is valid only if their rates of leaf appearance are the same.

Selection for date of ear emergence in ryegrass (J.P.C.)

The results of seven generations of selection for early and late ear emergence in ryegrass have shown that considerable additive genetic variation can be carried even within a small number of plants; response to selection is rapid and extensive, but a correlated decline in fertility has appeared in the later generations, possibly as a result of inbreeding.

This study has thus served as a pattern for similar selection studies on other physiological characters. In the present season, attention has been concentrated on the effects of back-selection after seven generations of response, and on the possibility of improving fertility by selecting within the early and late lines.

The physiology of the vegetative grass plant (P.B.V.)

The efficiency of nitrogen utilization by perennial ryegrass is being investigated in co-operation with Dr. E. L. Breese (Grass Breeding). Confirmation has been sought of previous data which suggested that it might be possible to obtain ryegrass plants with the same yield but different nitrogen content, or alternatively, different yields for the same nitrogen content. Either type of plant might be valuable according to specific agronomic requirements.

As the relative efficiency of different genotypes might be in part a function of growth stage and the level of nitrogen nutrition, tiller plants were utilized so that each genotype might be grown with adequate replication at different nitrogen levels and harvested at different times.

Twenty genotypes of S.24 perennial ryegrass were selected and the plants broken down into tillers and grown-on in boxes of garden soil. Three ' tiller generations ' were clonally propagated in this manner so that the tillers from all plants were reduced to a uniform nutritional history. Tillers were then prepared by rinsing them free of soil, cutting the shoots to a length of 4 cm. and the roots to 0.5 cm. before placing replicated tillers of each genotype in solution culture at levels of 140 p.p.m., 70 p.p.m. and 35 p.p.m. nitrate nitrogen. Harvest I was taken when the plants on the lowest level of nitrogen commenced to show nitrogen deficiency, harvest II was ten days later, and harvest III twenty days later.

Analysis of the variation of dry weight showed differences between nitrogen levels, harvests and the interaction of these to be highly significant. Differences between genotypes were also significant at the 1% level but there was no evidence of interaction between genotypes and other main effects. The genotypes do not therefore behave differently relative to one another, either at different nitrogen levels or different harvests.

The analysis of crude protein and carbohydrate data is as follows:

Analysis of variance and covariance of per cent crude protein and soluble carbohydrates (Five missing plots)

Item	*n*	*Per cent soluble carbohydrates*	*Per cent crude protein*	*r*	*Per cent crude protein corrected for covariation with per cent soluble carbohydrates*
		M.S.	*M.S.*		*Residual M.S.*
Nitrogen level (N)	2	4109.5	2312.8	–0.96	366.6
Harvest (H)	2	3629.5	2486.6	–1.00	257.3
N × H	4	172.6	222.3	–0.69	167.8
Genotypes (G)	19	39.1	7.5	–0.16	7.3
G × H	38	9.6	1.5	–0.13	1.5
G × N	38	15.0	2.9	–0.22	2.8
G × H × N (Error)	70	14.0	3.4	–0.16	3.6

Differences between nitrogen levels and harvests are again highly significant, with the crude protein varying directly, and the carbohydrate inversely, with nitrogen level. This is illustrated by the following data which show that with high nitrogen level or early harvest, crude protein is high and soluble carbohydrates are low; with low nitrogen or late harvest, crude protein is low and soluble carbohydrates are high.

Effect of nitrogen nutrition and harvest on soluble carbohydrates and crude protein (per cent)

N level (p.p.m.)		*Harvest (days)*		
		0	+10	+20
High (140)	Soluble carbohydrates	4.00	9.56	20.95
	Crude protein	28.60	20.70	11.10
Medium (70)	Soluble carbohydrates	7.50	21.92	23.65
	Crude protein	21.30	9.80	6.50
Low (35)	Soluble carbohydrates	19.99	30.50	33.20
	Crude protein	11.40	6.80	5.40

Thus the extremes are 4.0% soluble carbohydrates with 28.6% crude protein and 33.2% soluble carbohydrates with 5.4% crude protein. Overall differences between genotypes although of less magnitude than those brought about by nitrate variations are also significant at the 1% level.

To the breeder the greatest interest lies in the considerable genetic variation exhibited by all three characters, and when it is considered that the experiment involved only twenty genotypes taken at random from within one bred variety, the possibilities for selection become even more striking.

Tests of independence of the characters have been carried out. The last two columns of the first table on p.26 give a summary of covariance analysis of crude protein and soluble carbohydrates. High negative correlations are found for the nitrate and harvest effects and their interaction. Indeed, after removing covariation fromthe crude protein analysis the residual mean squares for harvests and nitrogen are no longer significantly greater than that for their interaction, thus indicating that as nitrogen becomes less available the increase in carbohydrate is almost exactly matched by a decrease in crude protein. No significant correlations were obtained between these two characters with respect to genotypic effects, therefore, the inherent capacity of the plants for a characteristic crude protein percentage is unaffected by carbohydrate percentage (and vice versa) under the conditions of the experiment.

The genotypic relationships between percentage carbohydrate and dry weight on the one hand, and the percentage crude protein and dry weight on the other, have been determined. In the first case this was non-significant ($r = 0.16$) indicating that carbohydrates are independent of dry weight for this range of genotypes. In the second case the appropriate graph suggested upper limits to the percentage crude protein which could be obtained with increasing dry weight, and this resulted in a negative and significant correlation. It was, however, by no means complete ($r = -0.62$). We may conclude, therefore, that over this range of genotypes and under these conditions the three characters show a high degree of independence and the prospects for selective improvement in all three traits are good.

Intraspecific differences in nutrient uptake and assimilation (P.B.V.)

Aluminium toxicity (P.J.R.). The effect of aluminium on phosphorus uptake by perennial ryegrass has been studied. It was

found that small amounts of aluminium either as pre-treatment or during the experimental period actually enhanced the uptake of phosphorus, but larger amounts decreased phosphorus uptake. Most of the phosphorus was retained by the roots, although the shoot presented the same uptake pattern but on a reduced scale. Increasing the phosphorus concentration of the medium fivefold greatly increased the phosphorus level in the root but did little to increase it in the shoot. It was found that there were varietal differences in phosphorus uptake between Melle (aluminium resistant) and Danish (aluminium susceptible).

Growing ryegrass at different levels of aluminium and calcium has shown that the poor root growth characteristic of aluminium toxicity is not identical with the reduced growth associated with low levels of calcium. In the case of aluminium, secondary roots fail to form properly and the initials show as protuberances on the main root. In the case of low calcium, lateral roots are actually formed but their development is much reduced.

Incidental observations suggest that it is possible to a certain extent to ' train' plants to receive higher and higher levels of aluminium. Manganese may possibly have a modifying effect on aluminium toxicity despite the fact that there is some evidence that varieties resistant to aluminium are susceptible to manganese and vice versa. These observations will be followed up.

The selection of aluminium-resistant lines continues, now being in the third selection generation.

Manganese deficiency. Studies in oats in co-operation with Dr. D. J. Griffiths (Cereal Breeding) continued. A subsequent experiment has confirmed, using a different technique, the characteristic variation at maturity in leaf and root manganese content of S.171 and Star (Vose and Griffiths, 1961).

It has been found for four manganese concentrations at three different levels of magnesium, that this difference primarily arises during the period between ear emergence and maturity, the leaves of Star increasing in manganese content rapidly between ear emergence and senescence. The decline in the concentration of manganese in the roots with successive harvests is a strong indication that manganese initially accumulated in the root system was subsequently redistributed to the shoots during the growing period. There was a tendency for greater concentration of manganese in the roots at the highest magnesium level.

The low magnesium treatment, although it resulted in little if any decrease in yield, very markedly affected the quality of the

grain, giving a larger proportion of husk. This effect on quality appears hitherto to have escaped attention.

The 1961 field work was concerned with definitely establishing certain varieties as susceptible or resistant to grey speck, both for further physiological work and also to enable known resistant breeding material to be obtained, while simultaneously the effect on the grey speck syndrome of different levels of potassium was also investigated. The first objective was achieved, as was also the development of a small-scale glasshouse test for resistance to grey speck.

The effect of potassium was greatly to increase grey speck symptoms to the extent in certain cases of completely eliminating grain yield. As little as 50 lb./acre of potassium was sufficient to increase symptoms.

Work was carried out on the translocation of manganese in oats, using Mn^{54}. It was found that Mn^{54} applied as a drop to the fourth leaf of manganese-deficient oat plants was concentrated in the stem and translocated primarily to the youngest developing leaf, or to the grain if present. Mn^{54} was readily detected in the roots but almost none was translocated to the first three leaves. More Mn^{54} was translocated in 96 hours than in 24, but little or no more was translocated in 192 hours. Mn^{54} present in the first two leaves of oat seedlings subsequently deprived of manganese was later redistributed to leaves four and five. Mn^{54} was found in leaves three and four even when the roots of seedlings were excised immediately after exposure to Mn^{54}, but more was detected if the roots were left intact. Plants which were given 0.5 p.p.m. stable manganese until they reached the fourth leaf stage and were then exposed to Mn^{54} showed a fairly uniform distribution of Mn^{54} throughout the plant. There was relatively little concentration at active growth centres.

The effect of manganese on the photosynthesis of grey speck susceptible and resistant varieties was investigated, using leaf discs and the direct method of Warburg. It was found that the optimum level of manganese for photosynthesis was the same for both resistant and susceptible varieties. This applied to both the whole reaction of the leaf and also to the oxygen evolution of isolated chloroplasts (Hill reaction).

Manganese toxicity. In co-operation with Mr. D. Gareth Jones (Herbage Legume Breeding) an experiment was carried out on varietal differences in manganese/calcium interaction in *Trifolium repens*, and this is reported elsewhere (see p. 54).

GRASS BREEDING

A. R. Beddows

Population studies in ryegrass (E.L.B., in collaboration with Dr. A. H. Charles, Grassland Agronomy)

With changes in farm practice since World War II, and an ever increasing urban expansion, the natural grasslands of this country which in the past proved valuable sources of breeding material are rapidly diminishing. It becomes important, therefore, to obtain collections from those areas which by virtue of their geographical situation and past history might provide valuable ecotypes for future breeding work. At the same time it is important to increase our understanding of the genetic situation underlying ecotypic differentiation and much could be gained from a study of populations deriving from habitats not too widely dispersed geographically but differing in certain definable conditions. Obviously the practical and fundamental aspects can profitably be combined.

The area chosen for initial consideration was the Monmouthshire flats (or moors) which occupy about 20 sq. miles along the south coast of Wales. The area is low-lying with a high water table and is very prone to flooding so that it is unsuited to ploughing. If well managed, however, it has the reputation of being valuable pasture land and as such has a long history. With the co-operation of Mr. R. Garrett Jones, N.A.A.S., clonal material of perennial ryegrass from 23 habitats, differing in soil type, water-level, salinity and management, were obtained from this area. At least 40 distinct genotypes were aimed at in each habitat by taking single tillers from a number of widely separated points.

A first experiment has been designed to discover differences between the populations grown as spaced plants and to see how stable these differences remain over a range of environments. The plants were grown under standard conditions for one year and then broken down into four equal tiller bunches. These were replanted in a replicated layout on four sites differing in aspect, altitude and soil. Data have been taken on a number of characteristics but so far only those on date of heading and on yield of a first hay cut taken on 16/6/61 have been analysed.

For both these characters there were wide and significant differences between populations. Overall differences between sites were also significant and in date of heading these could be related

Synecological data from Lolium perenne *populations*

Yield of spaced plants and per cent ryegrass in original swards			*Emergence date and management of the sward*		
Reference No. of population	*Mean yield per plant (gm.) on 16/6/60*	*Per cent ryegrass in the sward*	*Reference No. of population*	*Mean date of emergence*	*Management rating*
17	308	†	21	19/4	4
3	254	60	13	21/4	4
19	247	50	2	22/4	5
14	212	†	5	23/4	6
8	210	60	1	25/4	4
12	193	40	19	25/4	3
13	189	20	20	26/4	3
9	186	No data	17	26/4	†
18	181	††	7	27/4	6
4	179	††	14	27/4	†
15	178	25	9	28/4	3
20	178	40	11	28/4	4
5	170	35	23	29/4	2
7	168	35	6	29/4	2
16	158	30	8	30/4	1
21	154	30	22	1/5	1
2	154	10	16	1/5	2
11	151	20	3	2/5	2
6	149	50	4	3/5	1
10	149	20	18	3/5	1
1	142	30	10	3/5	2
23	135	7	12	3/5	1
22	67	5	15	7/5	1
	L.S.D. 44* (P=0.05)			L.S.D. = 4 days (P=0.05)	

† Reseeding suspected
†† Saltings with widely dispersed clumps of ryegrass
*Based on the mean square for interaction of populations and sites

Management rating
1 Sheep grazing only
2 Cattle grazing only
3 Grazing + hay alternate years
4 Sheep grazing + hay or silage cuts
5 Cattle ,, ,, ,, ,, ,,
6 Frequent hay

to variations in aspect and altitude with an expected pattern of north-facing or high-altitude sites tending to be later. Yield, on the other hand, was affected more by differences which could only be attributed to edaphic factors (predominantly soil-moisture and soil-fertility). The interaction of the two main effects, populations and sites, was non-significant for date of heading but highly significant for yield, so that in the latter case the relative performance of the populations was not the same for all edaphic conditions. Further analysis showed that this interaction was mainly the result of a geometric (rather than an arithmetic) increase in yield from unfavourable to favourable edaphic conditions, and as such should be removable by re-scaling ; this has not yet been attempted. The absence of non-scalable interactions, however, indicates that the relative behaviour of the populations with regard to yield as spaced plants can be predicted from one set of edaphic conditions to another. It is interesting to observe that the relative yields of ryegrass genotypes grown in culture solution are also predictable from one nutrient level to another (p. 25).

The overall population means are given in the table, together with least significant differences.

It will be noted that the L.S.D. for yield is based on the mean square for the interaction of population and sites without transforming the data, and as such is likely to be overestimated.

Although the yield measurements were taken on one date in the year it is clear that they are in no way associated with date of heading so that differences between populations do not spring from differences in the stage of growth.

Inherent differences between the populations must presumably have arisen in response to past selective forces and so should be relatable to the overall conditions which existed in the original habitats. Admittedly characteristics observed on spaced plants are not necessarily those which are important under sward conditions, for any particular reaction is likely to be a response to many interacting forces. Nevertheless, two clear relationships emerge from considering these results in relation to the past history of the populations. The first, which might be expected in the light of past experience, is that date of heading depends primarily on management in the sense that populations from habitats with a high frequency of cutting for hay or silage over a period of at least 20 years tend to be earlier than those under continuous grazing. An ar-

bitrary 'management rating' has been constructed for each habitat based on the frequency of cutting and the type of grazing (see table on p. 31) and the correlation coefficient between these and the date of heading (= –0.78) is high and significant at the 0.1% level.

A more novel relationship is that which can be discerned between the yield of spaced plants and the percentage ryegrass in the original habitat. The positive association is graphically portrayed (see Fig. 1), and the correlation coefficient (0.76) is significant at the 0.1% level.

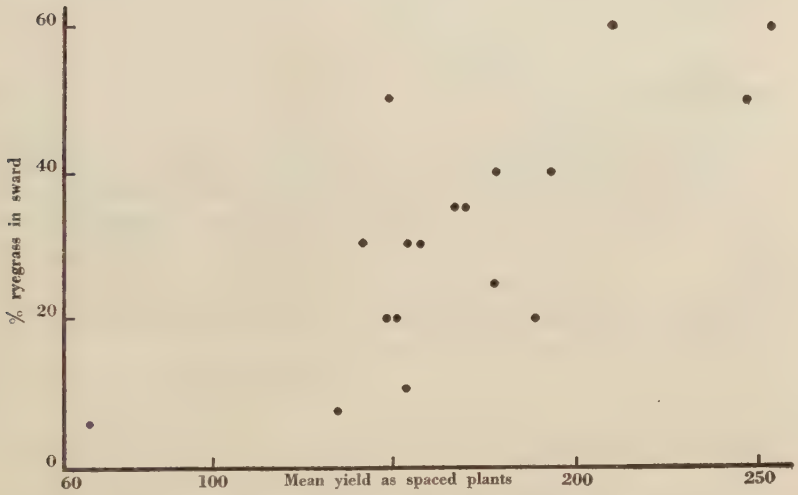

Fig. 1. Relation between yield as spaced plants and percentage ryegrass in original habitat

Thus the genotypes which are highest yielding as spaced plants are on the average those which have been most competitive under sward conditions. It would be most tempting to invoke the obvious corollary, but of course we first need to know much more about which components of growth have contributed most to this yield.

The percentage ryegrass is independent of management rating (r = –0.14) so that the yield potential as well as the frequency of ryegrass genotypes in the original sward must have depended predominantly on edaphic conditions. In this respect it is interesting to observe, as indeed might be expected, that the environmental factors which were found most strongly to modify genotypic expression are also those which exert the strongest selective force.

In summarizing we can see that this initial approach appears most promising. Genetic differentiation over a range of habitats has been detected and related to specific environmental differences. At the same time further problems have been posed. Thus in relation to the yield character just considered it is important to distinguish which components of growth are most responsible for yield and which edaphic factors mainly predispose this growth. The studies, therefore, set the stage for further genetic, physiological and agronomic investigations which should lead to a better appraisal of the individual plant in relation to its natural environment—the sward.

Amphiploidy in *Dactylis* (M.B.)

A study of fertility and chromosomal stability has been initiated in autotetraploid *Dactylis glomerata* subsp. *lusitanica*, and the allotetraploid based on the cross subsp. *lusitanica* × subsp. *aschersoniana*. Crosses have been made between autotetraploid subsp. *lusitanica* and selected tetraploid cultivar genotypes. This is the first stage of an attempt to introduce the desirable characteristics of *lusitanica* into a tetraploid variety.

Intergeneric hybrids (E.J.L.)

Experience with four intergeneric hybrids between *Lolium* and *Festuca*, previously described (*Welsh Pl. Breed. Sta. Rep.* 1956-1958, pp. 11-12) shows that the combination *L. multiflorum* × *F. arundinacea* is potentially the most promising from an agricultural point of view. Accordingly, it has received most attention recently and to date the primary aim has been to accumulate a large pool of fertile amphiploids before applying any selection.

Fourth generation seed is now available from the original crosses while a further and more extensive hybridization programme has yielded a large number of amphiploids which were intercrossed this year. Previous results had indicated that there are large genotypic differences in crossability and this programme was designed to include several genotypes from both species. Genotypic differences were again found and the more compatible crosses gave relatively large numbers of seeds which made it practicable to colchicine germinating seed rather than to employ the more tedious

method of injecting and capping tillers of fully grown plants, as was previously done.

Where doubling the chromosome number of a sterile hybrid restores fertility, as in this instance, it should be possible to produce fertile F_1 hybrids direct by using doubled forms of the parental species. This method is now being essayed. Tetraploid *L. multiflorum* (2n = 28) was crossed with dodecaploid *F. arundinacea* (2n = 84) during the summer of 1961. Good seed setting was obtained and over a hundred seedlings have become established. Their fertility will be assessed in 1962, and if it is sufficiently high we have at our disposal a far easier method of producing large numbers of fertile amphiploids.

There is now available a fairly wide range of relatively fertile material, and selection work will be started. The aim will be to produce a winter-hardy grass with quick establishment and early spring growth capable of high production over four to five years. Special attention will be paid to the features listed below: + indicates the contributing species for each character.

Desirable features	*L. multiflorum*	*F. arundinacea*
Quick establishment from seed	+	—
Good production in seeding year and spring of 1st harvest year	+	—
Early spring growth	+	+
Palatability	+	—
Winter hardiness	—	+
Persistency	—	+
Continued high production after 2nd harvest year	—	+

Superimposed on this will be the need for rigorous selection for higher seed setting ability.

Growth stage and chemical composition (I.D., in collaboration with Dr. D. I. H. Jones, Chemistry).

The chemical composition and therefore the nutritive value of herbage varies with the growth stage. It is important, therefore, to assess the effects of defoliation in relation to the stage of growth and to see how they may in turn affect the chemical constitution of the regrowth. At the time of the flush of spring growth associated with stem development, it has been shown that a critical stage occurs when defoliation involves the death of most stem tillers. The method of recognizing this stage and the time of its occurrence varies with the species and with varieties within species (*Rep. Welsh Pl. Breed. Sta.* 1960, p. 60). The present experiment was set up to investigate the effect on this critical stage of close defoliation early in March prior to stem development, and to trace the influence of such defoliation on the chemical composition of regrowth subsequent to cuts in mid-April or early May.

The material used was S.24 perennial ryegrass and the experiment involved two series of plots: (A) no early spring defoliation, and (B) two cuts (to $\frac{3}{4}''$) taken during late February and early March. The number of stems over $1\frac{1}{4}''$ (the minimum height at which stem apices can be removed by usual farm implements) was determined in both series each week from mid-March to late May. In each series half the plots were cut at $\frac{3}{4}''$ on 18 April and the remaining half on 2 May, and in both the regrowth was sampled after four weeks. The relevant data are given on p. 37.

There was little further increase in stem number after 25 April in Series A, and after 2 May in Series B, which in each case was 2 days prior to initial head emergence.

The early defoliation led to an initial retardation of stem elongation in Series B and consequently the first main cut on 18 April resulted in little loss of stem in this series but a heavy loss in Series A. The cut on 2 May led to the death of most stem tillers in both series. The total yield of regrowth is evidently chiefly a function of the stem-tiller contribution. For any given main cut the percentage fructosan in the regrowth increases markedly with the number of stems, while the percentage total sugars slightly decreases.

The effect of the early March defoliation, therefore, was to delay stem development, which resulted both in higher yield and

Chemical composition and yield of S.24 perennial ryegrass relative to stem extension

	Series	No. of tillers per sq. ft. having stems over $1\frac{1}{4}$"	No. of stem tillers removed/sq. ft. in		Regrowth data			
					Yield (gm.)/sq. ft.		Chemical analysis of ryegrass fraction	
			Main cut	Regrowth cut	Total herbage	Stem tillers	Per cent Total sugars	Per cent Fructosan
Main cut 18 April	A	154 Mean from 25/4 onwards=189	117(18/4)	21(16/5)	16/5: 7.9	0.5	11.2	6.0
	B	13 2/5 onwards=158	8(18/4)	128(16/5)	16/5: 13.2	5.6	9.4	12.4
Main cut 2 May	A	173	166(2/5)	14(29/5)	29/5: 7.2	0.3	12.2	10.2
	B	140	116(2/5)	44(29/5)	29/5: 8.6	1.3	10.8	12.9

higher fructosan content in regrowth following early silage cuts and this was particularly so after the cut on 18 April which, for the defoliated series, was a fortnight prior to the critical growth stage.

In further work the influence upon yield and chemical composition of delaying the harvesting of the regrowth will be studied.

The effect of environmental aspects on vegetative growth in grasses (T.I.E.)

An experiment concerning the vegetative development of various agricultural grasses was initiated in 1958. Eight species, representing one to five varieties, were studied during four consecutive years under field conditions and in the glasshouse. In the latter, the temperature, light intensity and day length were partially controlled while in the field concurrent day-to-day measurements of these factors were obtained. Growth analysis was carried out on the basis of vegetative reproductive organs (shoots and tillers).

Growth analysis showed that the net assimilation rate increased with increasing light intensities as did also the critical leaf area index. Since under natural conditions the light intensity depends primarily on the angle of the sun above the horizon, it follows that the critical leaf area index should vary with season and latitude in a predictable manner. The experiments confirmed this and as a consequence it has been suggested that growth analysis would be more usefully based on a light scale than on a time scale so that comparisons may be extended over a range of environments. This work has been prepared for publication and will appear shortly.

Temperature had a marked influence on the rate of leaf appearance and rate of tillering, both being arrested at a higher minimum temperature than leaf expansion (i.e. exponential growth has a higher threshold temperature than linear growth). Threshold temperatures varied between and within species but were not highly correlated with the time of floral development. Consequently winter productivity and earliness as classified by date of ear emergence are also not highly correlated.

The effect of quantum radiation upon net assimilation rate was more closely related to day length than light intensity especially in the decreasing regimes. This is in harmony with previous findings which showed that the percentage usefulness of radiation energy for identical foliage is higher at the lower intensities.

The total variation, genetic and environmental, for total leaf area was considerably less than was observed for average leaf size, rate of leaf appearance or rate of tillering. Despite the very wide genetic differences observed for these characters, selection for one or other alone would thus not be likely to influence the total leaf area to any great extent.

The size of individual leaves was affected by most of the environmental conditions. The length showed a much larger variation in this respect than the width and it is concluded that environmental influence is exercised primarily upon cell size rather than upon cell number. The Kemp technique was therefore applicable to the determination of the area of individual leaves under all treatments.

There were considerable interactions between genetic effects and the observed environmental factors taken individually for all the characters examined. In most cases higher order interactions were also evident. This indicates that response to any set of environmental conditions is fairly specific and warns against expecting efficient usage from a so-called general-purpose variety over a wide range of environmental conditions. It also warns that for these characters varietal comparisons under field conditions must be carried out with some caution. For instance, the rate of leaf appearance is differentially affected by temperature, thus leaves of a particular status will be produced at different times by different varieties and consequently genetic variations in leaf size will be confounded with environmental effects.

HERBAGE LEGUME BREEDING

W. Ellis Davies

Investigations on polyploid clovers (A.M.E.)

New material. New polyploids were produced from the following diploid varieties:

White clover—Aberystwyth S.100 Nomark
Red clover —Aberystwyth S.123 Nomark
Lakeland, resistant to mildew (*Erysiphe polygoni*)
Pearse, resistant to eelworm (*Ditylenchus dipsaci*)
Aa 3531, selected for resistance to clover rot (*Sclerotinia trifoliorum*)
Dollard, a good early variety.

The same genotypes at the two levels of ploidy were retained so that critical comparisons could be made between the diploids and the polyploids and it could be ascertained whether superior diploid genotypes were also superior at the tetraploid level. A small quantity of tetraploid seed of these varieties is now available for breeding and multiplication.

Assessment of breeder's material of polyploid white clover. Data were taken of green and dry matter yields, percentage clover and percentage crude protein from a third year stand of plots of polyploid white clover and of S.100 Nomark when sown with S.24 perennial ryegrass, and from a second year stand of clovers planted under a timothy/meadow fescue mixture. Irrespective of the companion grasses and the method of clover establishment the pattern appeared to be that some of the polyploid families gave significantly higher yields than the diploids in the third (and fourth) cuts, but were generally lower yielding early in the season. It appears that there might be a place for polyploid white clover in long leys and where production is required in late summer.

Trial of European varieties of tetraploid red clover. Some continental varieties of tetraploid red clover and the diploid varieties from which they were bred were compared with Aberystwyth tetraploid red clover (AA8) and Aberystwyth S.123 and S.151

diploid red clovers under spaced plant and drill conditions at two locations. Some of these varieties were also included under plot conditions in a trial by Mr. D. G. Miles and Mr. I. G. Williams (Grassland Agronomy). The table shows some of the results:

*Relative yields of four tetraploid varieties and S.*123 *under drill conditions (S.*123 *at* 100 *for both cuts)*

	Cut 1	*Cut* 2
Aberystwyth diploid S.123	100	100
Aberystwyth tetraploid AA8	123	118
Weibull's Rea, South Sweden	124	94
Svalöf's Ulva, Middle Sweden	84	65
Jokioinen TPA.1, Finland	114	59

The Aberystwyth tetraploid AA8 was generally the highest yielding variety, the South Sweden variety being the best foreign type under the conditions of the trial. Superior genotypes from the varieties tested will be included in the breeding material of tetraploid red clover in order to increase the variability.

Effects of selfing tetraploid red clover. Tetraploid red clover often exhibits greater self-fertility than diploid varieties so it is important to discover whether selfing reduces productivity. Although under field conditions 'foreign' pollen would be favoured in competition with 'self' pollen it is possible that *some* selfing would occur and therefore this factor cannot be ignored.

In this investigation the effects on productivity of selfing tetraploid red clover through three generations were recorded on plants in the glasshouse:

Data relative to original family at 100

Generation	*Yield at full flowering*	*Tiller No.*	*Tiller length*
Original family	100	100	100
1st generation selfing S_1	109	94	100
2nd ,, ,, S_2	74	73	93
3rd ,, ,, S_3	59	63	88
Diploid control variety	98	153	96

The data demonstrate that in the first generation of selfing there is a consistent but non-significant increase in yield, tiller length is maintained and tiller number is somewhat reduced. In the second and third generations of selfing there is a steady reduction throughout.

Effect of gibberellic acid on seed setting in polyploids. Four sq. yd. areas in polyploid red and white clover seed islands were sprayed with GA at early stages of internode elongation. The most significant effects of treatment were a shortening of the flowering period which facilitated even ripening of seed, and an increase in the number of flower heads/sq. yd. due to the increased branching in the tillers:

Species	*Wt. of seed (gm./4 sq. yds.)*
Tetraploid red clover	
Treated with GA	141.5
Untreated	129.5
Polyploid white clover	
Treated with GA	64.7
Untreated	45.5

The results show a significant increase in seed yield from treatment with GA to the extent of about 10% in red clover and 30% in white clover. This preliminary experiment may have important applications for the improvement of seed yield in polyploid clovers, particularly in experimental plots and at the initial multiplication stages.

Species relationships and nodulation of *T. hybridum* and *T. ambiguum* (A.M.E.)

A field experiment was set out to find how much natural crossing occurred between *T. ambiguum* and *T. hybridum*. In one block clones of *T. ambiguum* were surrounded by single plants of *T. hybridum*, and in another the reverse arrangement was adopted. Five blocks in all were established, using the species at different levels of ploidy. A few seeds have been harvested

from the cloned plants and are being tested for hybrid nature. In conjunction with Mr. D. Gareth Jones this material is also being used for the study of nodulation. *T. ambiguum* requires a specific *Rhizobium* not normally present in our soils before it will nodulate effectively. The graft and sexual hybrids of *T. ambiguum* and *T. hybridum*, however, will nodulate with the *Rhizobium* effective for *T. hybridum* present in our soils. The investigation is concerned with the effect on *T. ambiguum* of inoculum after repeated transfer through the graft and sexual hybrids.

Fertility relationships in *Lotus* species (A.M.E.)

The aim of this investigation is to introduce into *Lotus corniculatus* those desirable characters which are present in *L. uliginosus* and *L. tenuis*. *L. corniculatus* shows low seedling vigour, slow establishment and loss of seed due to shattering. *L. tenuis* has greater seedling vigour than *L. corniculatus* and the seed pods of *L. uliginosus* do not shatter easily.

Tetraploids have been produced from the diploid species *L. tenuis* and *L. uliginosus* to facilitate hybridization with the tetraploid *L. corniculatus*. A few hybrids have been produced after artificial culture of the embryo. More seeds of the polyploids and hybrids were produced in 1961 for future use in field experiments.

Assessment of breeder's material: Spacing lucerne (W.E.D.)

Earlier results showed the unreliability of the yield of the widely-spaced single plant in predicting the yield of the same material under more practical broadcast sowing conditions. It had been shown, however, that a plant population of between 16 and 9 plants/sq. ft. gave comparable, or relatively similar, results to those from broadcast sowings. The present experiment examined in detail the reaction to various arrangements and spacings based on populations of between 16 and 4 plants/sq. ft.

Seven polycrossed progenies of early types of lucerne selected on the basis of their differential behaviour at close and wide spacings with Du Puits as control, were used as the test material, the spacing being 3″ × 3″, 4″ × 4″, 6″ × 3″, 6″ × 6″, 12″ × 3″ and 12″ × 6″. Significant variance ratios were obtained for progenies and spacings,

but the interaction of spacing × progenies was not significant, thus indicating that in this material all progenies reacted similarly to the plant spacing. The highest yield of dry matter and crude protein was obtained from the 4″ × 4″ spacing, and the lowest (20% less) from the spacings 12″ × 3″ and 12″ × 6″.

Data for the second harvest year have been collected, but have not yet been analysed.

The breeding of a new large-leaved white clover (W.E.D.)

The aim of this project is to produce a large-leaved, tall-growing, persistent white clover which will be able to compete more successfully with some of the more vigorous grasses now available, especially in the presence of applied nitrogen. Ladino clover has the desired morphological characters, but its performance in Britain is poor, and it has been crossed with S.100 white clover in order to improve persistency. The current selections are now in the third and fourth generations, and have undergone a period of up to three harvest years of testing in grass swards under a silage and grazing management. This method of assessment has been necessary because poor correlations have been obtained between the yield of spaced plants of white clover, and of clover in the corresponding swards.

Many of the progenies have proved superior to S.100 Nomark, more especially in dry periods in the late summer, and their general recovery after cutting has been quicker. The faults of Ladino have not all been entirely eliminated; some of the progenies are rather susceptible to clover phyllody, and also have suffered as a result of their palatability to slugs.

A seed increase island harvested in 1961 gave a poor yield, due to drought conditions at flowering time, and also to the excessively wet weather at harvest. A further area has been planted with cuttings from the seven best families in the sward trial 1957-1961.

This project has been widened by the inclusion of material of Mediterranean origin which has the same general morphological characters as Ladino, but because of high content of cyanogenetic glucoside is not so palatable to slugs. Ecotypes obtained from Israel and Turkey have been quite promising, although the former tend to suffer from winter damage.

Lucerne breeding (W.E.D.)

The aim of this programme has been to produce two main improved types:

Early lucerne. Selections from early Flamande lucerne have been polycrossed and the progenies grown in trials for up to three harvest years. In the last of such trials many of the progenies showed outstanding gains in dry matter, yield of crude protein and resistance to leaf spot, compared with the control variety Du Puits. The best of these selections will be combined to form a synthetic variety for further testing. A diallel cross from the seven best plants in a previous polycross was established in the field during 1961 to obtain more detailed information on the breeding potential of these plants.

Creeping-rooted lucerne. The original creeping-rooted plants from Dr. Heinrichs, Saskatoon, were agronomically unsuited for growing in this country, and these have been crossed with a Flamande-type lucerne and with progenies of Du Puits/Rhizoma in order to introduce more vigour into the creeping-rooted plants. In the F_1 crosses the creeping-rooted character has taken from 15 months upwards to become manifest, but some progenies established in 1959 showed very strong lateral development during 1961. The best of these will be selected for further breeding. Selfings of the F_1 plants were also established in the field in 1960, but to date (14 months afterwards) there is little evidence of the creeping habit.

The persistency of sown white clover in a long ley at an upland centre at an altitude of 1000 ft. (W.E.D.)

Very little is known about the type of clover that persists in swards under a given set of conditions. Such information would be of value to the plant breeder in order to assess the current varieties, to study changes that occur, and also as a source of breeding material for future work. Such a study, however, is rather complicated in white clover because of the difficulty of identifying varieties, the presence of buried seeds of indigenous clover, and also that the grazing animal may bring in seeds of other types. There is often an opportunity for crossing between these clovers, and very little is

really known of the significance of self-seeding and the relative persistency of a single plant of clover.

The material used in this study was obtained from an area sown in 1949 with five ryegrass varieties and a mixture of 2 lb. N.Z. Certified Mother seed, and ½ lb. Aberystwyth S.184. Samples of five white clover populations were obtained in 1958 and established as spaced plants in the field in 1959. Each population consisted of 67 to 79 plants laid out in four replicates. The main data were collected in 1960, but only the data for leaflet length and leaf marks will be discussed here. Current stocks of N.Z. Certified Mother and S.184 seedling plants were used as controls.

Distribution of leaflet length in five populations of white clover from an original seeding of New Zealand Certified Mother and S.184 white clovers.

	Leaflet length (mm.)														
ex ryegrass sward	11	13	15	17	19	21	23	25	27	29	31	33	35	*Total*	*Mean*
S.23 + commercial	2	4	13	16	16	9	3	4	—	—	—	—	—	67	17.9 ± 0.760
S.23	3	5	7	20	19	11	11	3	—	—	—	—	—	79	18.4 ± 0.802
S.24	1	4	8	17	15	10	9	4	—	—	—	—	—	68	18.6 ± 0.769
S.101	—	4	9	11	16	14	9	9	—	1	1	—	—	74	19.2 ± 0.823
Ba 4457	3	2	7	8	16	20	8	9	3	2	1	—	—	79	20.2 ± 0.832
S.184 (control)	—	—	2	1	7	12	8	6	2	—	1	1	—	40	22.0 ± 0.786
N.Z.C.M. (control)	—	—	—	—	3	4	6	6	6	6	2	1	2	36	25.8 ± 0.945

The leaf size of the five populations was significantly less than that of the controls, and there was a general shift towards a smaller leaf. The larger-leaved types were eliminated, only 2% having leaves larger than 25 mm., compared with 10% in S.184 and 47% in N.Z. Certified Mother. There was a corresponding increase of plants with leaflets less than 15 mm. There was some evidence of variation between populations, the white clover leaflets from Ba 4457 being significantly larger-leaved than those from an S.23 + commercial ryegrass sward.

Such a change in leaf size could be due to loss of vigour in the vegetative cuttings as a result of the build-up of pathogens, viruses, nematodes, etc., but the appearance of so many smaller wild types suggests that this was due in part to the incursion of indigenous clover.

A different type of evidence of the changes occurring could be obtained from studying the frequency of leaf marks as shown by the data:

Frequency of leaf marks	*Leaf marks*				
	None	*Yellow*	*Others*	*Total*	χ^2
Observed pooled frequency in 5 populations	63	7	304	374	—
Expected in S.184	50.2	9.3	314.5	374	4.16*
,, New Zealand C.M.	23.4	8.6	342.0	374	71.6
,, Original sowing	28.9	8.6	336.6	374	43.6

* P = 0.20 – 0.10

The calculated χ^2 values indicate significant deviations of the observed values of the pooled five populations from expected values in N.Z. Certified Mother and the original sowing, but not for S.184. This evidence again confirms the selective elimination of the New Zealand type white clover. A parallel situation is also found in the frequency of an anthocyanin allele R^f which is independent of the ordinary *V* markings. The observed frequencies depart very significantly from those for New Zealand, while in comparison with S.184 there is a smaller but significant departure.

It is apparent that under such conditions of hard continuous grazing by sheep and at a relatively high altitude, the larger-leaved types are eliminated, while the smaller-leaved types are able to persist.

Indigenous white clover from old pastures (W.E.D., N.R.Y.)

Collections of grasses were made at 23 sites, mainly in Monmouthshire, by Dr. E. L. Breese (Grass Breeding) and Dr. A. H. Charles (Grassland Agronomy), and the white clover plants in the divots were rooted in the glasshouse before being grown in the field. The original sites were very varied and included saltings, cliff top swards and fields used as permanent pasture for sheep or cattle or cut for hay or silage. Data were collected on leaf size, spread, height, weight and flowering date.

The material belonged to the typical indigenous wild white clover in this country and was remarkably uniform. For example, the mean leaflet length varied from 9.7 mm. to 13.3 mm., compared with 12.8 mm. for a typical Kent wild white clover sample. The leaflet lengths in two populations, one from a salting and the other from a dry cliff top sward, were significantly less than the overall mean. The largest leaved plants came from the better pastures, and as a

rule this was applicable to all size characters. The mean flowering date was similar to Kent, and the mean of all, with one exception, fell within a period of five days.

Symptoms of stem-eelworm were observed in most of the populations, and in three, more than one-third of the plants were infected. Since the plants were grown in close proximity to each other prior to planting out it is not known whether the infection spread from one lot or was widespread in the original material. The infected plants were visibly less vigorous and suffered more under dry conditions. The finding of eelworm in this material and in other indigenous plants in the last few years may be a matter for future investigation should it prove to be widespread.

The conclusion with regard to indigenous white clover is that in British indigenous material the range of variation in gross morphological characters is small. It may be, however, that selection for physiological conditions, for example, salt tolerance in this instance, could have taken place in these populations.

The stability of Merkur and S.123 red clovers when multiplied away from their region of origin (W.E.D., B.F.T., in conjunction with Svalöf Plant Breeding Station, Sweden).

This project was started in 1948 when it was originally proposed to multiply up to five generations at each Station: Merkur at Aberystwyth and S.123 at Svalöf. Five generations of seed of Merkur were obtained at Aberystwyth up to 1959, but unfortunately only two lots were available from Svalöf. Seed of the various generations and of the original sample had been kept in cold storage, and the experiment was set up in 1960 at Svalöf and at two centres at Aberystwyth, at elevations of 70 ft. and 750 ft.

During 1961 data were collected on spring growth, plant type, flowering time, number and height of tillers, green and dry weights. Preliminary information has shown little change in flowering time of Merkur at the lower centre at Aberystwyth. There has, however, been a steady increase in the length of the longest tiller in the spaced plants and drills, and the fourth and fifth generation plants have been significantly taller than those from the original seed, or from the first and second generations. The final assessment of the results will be made when all the data have been completely analysed.

Potentiality of legumes for hill conditions (W.E.D., B.F.T.)

There is a need for a herbage legume that can survive better than white clover on poor, acid, dry soils of low fertility. It has been suggested that *Lotus* spp. may have some potential in this respect, and accordingly 25 varieties/ecotypes of *Lotus corniculatus* (21) and *L. uliginosus* (4) were assembled from North America, Europe and New Zealand, and established in two trials. The first trial is at Tynpynfarch, at an altitude of 750 ft. and the second at Pwllpeiran, 1250 ft. sown in July 1960 with S.23 perennial ryegrass as the companion grass. Three varieties of white clover, S.100 Nomark, S.184 and Kent, and two of red clover, S.151 and S.123 Nomark, were included as controls. The plots are grazed by sheep and some pre-grazing samples are taken.

At the lower centre two varieties of *L. uliginosus*, one from the Azores and the other from Germany, were outstanding in the autumn of the seeding year, but they petered out very rapidly during the winter. The early spring growth of *Lotus* was slow in comparison with white clover, and the companion grass was paler green. At the two last cuts *Lotus* on the average was slightly better than white clover, and some of the best varieties, e.g. Viking, and Stirpe 9 from Italy, were very good. The yield of white clover and *Lotus*, however, was less than that of the red clover.

At the upper centre the level of legume production was very much lower, and under these conditions the *Lotus* plots were better than the clover plots. It is too early, however, to assess these results. The level of fertilizer application at 10 cwt./acre ground limestone, 2 cwt./acre muriate of potash and 2 cwt./acre superphosphate have been kept to a minimum in order to have the reaction of these ecotypes at low fertility. A further trial containing many French ecotypes was established in 1961 at a third centre.

The effect of continued selfing in *Trifolium fragiferum* (W.E.D., N.R.Y.)

It is a general rule in the genus *Trifolium* that annuals are self-fertile and perennials are self-sterile. There are exceptions, however, and *T. fragiferum* has been reported as a self-fertile perennial. An examination of this clover revealed that lines of north European origin were more self-fertile than the one of Palestinian origin. In view of the presence of this amount of self-fertility it

was desirable to see what effect inbreeding would have on plant vigour, and whether a degree of outcrossing was necessary to maintain maximum vigour. Three lines of *T. fragiferum* clover from France and one from Palestine were selfed to the fourth generation, and all generations were grown in one experiment in the glasshouse. Data were collected on percentage seed set, germination, rate of leaf development, tillering, leaf size, petiole length, green and dry weights. It was found difficult to maintain the Palestine material, and there were generally insufficient plants available for detailed study. There was, however, ample material of the three lines of north European origin and there was a steady increase in mean percentage seed set from S_0 to S_3. There was some unavoidable selection for increased seed set in the continuation of the lines. For the other characters, especially green and dry weights, there was a slight drop from S_0 to S_1, but this was more than regained by S_4 in two of three lines. In the other line the drop continued to S_3 when there was some recovery. The S_4 inbred generation showed much more variability for some characters, especially percentage germination and dry matter weight, than the earlier generations.

The behaviour of these lines to date has been mainly typical of an inbreeding system, with perhaps a small amount of outcrossing, while the lines of Palestinian origin reacted mainly in the manner of an outbreeding system.

The flowering of white clover under glasshouse conditions (W.E.D., N.R.Y.)

The small number of flowers produced by white clover plants grown in glasshouses is sometimes a limiting factor which curtails the breeding programme. Two important contributory causes of this were thought to be the artificial shading of the glass to reduce inside temperature and excessive watering. Twenty cuttings were obtained from each of four clones selected in 1959 on the basis of their flowering propensity. When established they were planted in 1-gal. glazed pots, and the following treatments applied on 8 April, one month later:

Two light treatments:		*Water level maintained below surface at*
(a) Normal daylight inside glasshouse (b) Shaded with muslin cage which was calculated to be 0.5 the daylight of (a)	X	2″ 4″ 6″

There were three replicates of each treatment. The effects of shading are shown below:

	Number of flowers per pot		
	Normal daylight	*Shaded*	*Mean*
Clone 1	37.2	20.0	28.6
,, 2	82.6	18.9	50.8
,, 3	178.3	101.9	140.1
,, 4	250.1	119.8	184.9
Mean	137.1	65.1	101.2

Shading drastically reduced the number of flowers, and this effect was noticeable during the observations from May to July. In the plants receiving normal daylight the amount of flowering was relatively the same as in the previous season when they were first selected, and the figures show that Clone 4 produced more than six times as many flowers as Clone 1. The interaction clone × shading was highly significant, and Clone 2 suffered more from shading than the others. The effect of water levels was inconclusive, and the 20% decrease in number of flowers from the 2″ water treatment did not reach a significant level. The actual date of first flowering was not affected by these treatments.

From these results it would appear that shading has a deleterious effect on flower production, and this should be considered when shading the glasshouse to reduce temperature. There is evidence that some genotypes suffer more from the effect of shade than others.

Clover phyllody (W.E.D., B.F.T.)

The incidence of clover phyllody has continued to increase in the clover nurseries. In general the larger-leaved varieties, especially of the Ladino type, show a higher incidence than the small-leaved wild white types, e.g., S.184 and Kent. The effect of the virus on plant vigour has been observed in spaced plants, and initially the infected plants are larger than the non-infected. This may be due to the fact that the larger the plant the more likely is it to become infected. In later cuts, however, the infected plants showed a decrease in vigour amounting to about 10%. Clover

plants in swards show a much lower infection than as spaced plants under otherwise similar conditions. So far no plants have been found which are resistant to the virus under natural field conditions, but the search is continuing.

Spraying treatment for control of leaf hopper (in conjunction with Advisory Entomologists and Pathologists, N.A.A.S. (Wales), Trawscoed). The setting up of this experiment in 1958 was described in *Rep. Welsh Pl. Breed. Sta.* 1959, p. 63. There were three spraying treatments, DDT/BHC and Demeton Methyl applied fortnightly when leaf hoppers were expected (except when the clover was in full flower); DDT/BHC was used twice in the autumn and twice in the spring. By the end of the first harvest year 18% of the plants were infected following a small peak of leaf hopper activity in July/August. The average infected plants was 64% by June of the second harvest year, and there was little difference between the sprayed and non-sprayed (control) plots.

Counts of leaf hoppers in the sticky traps reached very high numbers in June, and again in the August/September period. The apparent July trough in leaf hopper numbers could have been due to the management of the crop as the plants were cut during this period. By late summer it was not possible to distinguish the white clover plants as they had grown into each other, so that no further data on phyllody frequency could be collected. The most frequent species of leaf hopper caught in the traps was *Macrosteles sexnotatus*.

The control measures used here have been unsuccessful although 75% of the area had been sprayed with insecticide. This may be due to the individual plots (20 yds. × 5 yds.) being too small in relation to the surrounding area which provided shelter for the leaf hoppers. The data for peak population density of leaf hoppers should be useful in planning further experiments.

Microbiology: A survey of rhizobial isolates (D.G.J.)

The testing of nodule isolates from many areas has been continued and their effectiveness in nitrogen fixation assessed in comparison with a known effective rhizobial strain. The tester variety of white clover was S.100 Normark, and the method was based on a comparison of dry weights after 70 days, as described in *Rep. Welsh Pl. Breed. Sta.* 1960, 39-40.

There are numerous limitations in this kind of bacterial survey to get a true indication of the distribution of effective or ineffective

strains. For example, both types have been isolated from the one plant root system, thus sampling on an extensive scale is of little value. These limitations, however, were lessened by using an intensive technique which involved sampling plants at random points within a radius of 6 ft., washing the roots, excising the nodules and grading them according to size. The nodules for testing were selected at random from the total number, but in proportion to their size distribution. The aims of this survey were, firstly, to obtain a distribution pattern of effective and ineffective strains in an attempt to correlate strain effectiveness with soil type or altitude, and, secondly, to search for more effective strains than those already in the laboratory collection.

In Scotland and Wales a greater proportion of ineffective and intermediate-type strains was found on peaty soils than on mineral soils. This would suggest that the use of a very effective rhizobial strain as an inoculum on upland peat might prove beneficial. This has been shown to be true and is discussed in the next section.

Nodule isolates from the mineral soils where clover had failed showed that no ineffective strains were present and applying superphosphate produced twice the number of nodules per plant together with an increase in nodule size which resulted in a vigorous clover crop.

The use of the very effective strain TYN which was isolated in this survey from a mineral soil at 750 ft. near Aberystwyth proved very valuable as a tester strain in the laboratory and as a field inoculant. Another very effective strain, K9, was isolated from a plant of Kersey white clover. It is hoped that more information will be gathered from the continuation of this survey, especially regarding the distribution of ineffective rhizobial strains.

Field inoculation trials (D.G.J., W.E.D.)

In a collaborative field experiment with Mr. Roy Hughes and Mr. J. M. M. Munro (Grassland Agronomy) an inoculation treatment was included in an attempt to measure the nitrogen contribution of clover on an upland peat and an upland mineral soil. The white clover varieties were S.100 and S.184, and the rhizobial strain TYN was used as the inoculum.

On the peat soil at an altitude of 1600 ft. there was a very marked effect from inoculation. The uninoculated plants were very small and yellow, whilst those which had been inoculated

were very vigorous and dark green. Nodulation was profuse on the inoculated plants, each having many large fleshy nodules, often crimson in colour. The uninoculated plants, however, were sparsely nodulated and when present most of the nodules were small and white. The uninoculated clover plants were obviously nitrogen-starved, and very few were making any growth at the onset of winter. An examination of the roots of those that were growing showed good nodulation. The success of the inoculation on this peat area can be attributed to the absence, or near absence, of rhizobial strains, and it appears that those that were present were very inferior to the introduced strain in effectiveness in symbiosis.

There were no visible effects of inoculation on the mineral soil but nodule samples have been taken from all plots and are under test for their effectiveness with the standard tester variety S.100 Nomark.

The interaction of calcium and manganese on nodulation and growth in three varieties of white clover (D.G.J., P.B.V.)

Three varieties of white clover, S.100 Nomark, Szolnok and White Dutch were selected after a preliminary experiment in which a number of white clover varieties were investigated for their calcium and manganese content after growing in three soils of low, medium and high calcium (*Rep. Welsh Pl. Breed. Sta.* 1959, 19). The variety White Dutch was highest in calcium on the low calcium soil, S.100 Nomark had a high manganese and low calcium content on the low calcium soil, and Szolnok was high in calcium and comparatively low in manganese on the low calcium soil.

In this experiment done in pot culture with a liquid nutrient solution, the three varieties were grown under two levels of calcium, 20 and 80 p.p.m. and four levels of manganese, 0.5, 10, 20 and 40 p.p.m. No consistent varietal differences in manganese content appeared, but in the case of calcium the variety White Dutch showed a much lower content than the other two varieties at the highest level of manganese.

Yield data showed a consistent decline with increasing manganese and there were marked varietal differences in the degree of response to the increase in calcium. Nodule numbers decreased significantly with increasing manganese. High calcium reduced the adverse effects of manganese in all varieties except Szolnok. Nodule volume showed the same pattern of response as nodule

numbers, with Szolnok again providing the exception. We came to the conclusion that manganese and calcium are important for the nodulation and growth of these varieties and that resistance to manganese toxicity varies considerably.

Investigation of a sample of lucerne seed inoculated by the vacuum method. (D.G.J., W.E.D., B.F.T.)

A sample of lucerne seed was obtained which had been inoculated by the method used commercially in America, which, it is said, forces the rhizobia under the seed coat by the release of a vacuum. It is claimed that by this method the bacteria remain viable for long periods and thus if proved successful could become a universally accepted method of inoculation.

The method of testing was to sow seeds of the inoculated sample in test tubes using agar containing a plant nutrient solution but lacking combined nitrogen. For comparison uninoculated seeds from the identical source were sown under sterile test-tube conditions in the same way as were seeds which had been inoculated with a strain of *Rhizobium melilotii* from this laboratory using the skim milk method.

The results are shown in the table:

Treatment	*Mean nodule number*	*Per cent plants nodulated*	*Mean harvest dry weight (mgm.)*
Vacuum method	6.2	36.3	10.0
Control	3.1	43.7	16.3
Skim milk method	8.7	97.8	34.1

This investigation was also carried out in the field without the uninoculated control, as a direct comparison of inoculation methods. Cutting data are shown in the table:

	Cuts (lb./acre)			*Total yield (lb./acre)*
	First	*Second*	*Third*	
Vacuum method	930	1700	1960	4590
Skim milk method	1890	2210	2220	6320
L.S.D. at 5%	718	440	252	1113

The viability of the rhizobia on the seed inoculated by the vacuum method was very poor, in fact in the test tube experiment this technique produced no better nodulation than from the uninoculated seed used as the control. The data from the laboratory experiments were substantiated by the field trial. Seed is now available of red clover inoculated by the same method and this will be tested in the same way.

CEREALS, BEANS AND *BRASSICAE* BREEDING

D. J. Griffiths

CEREALS

During the year under review some changes were introduced in the method of handling small scale yield trial plots in the breeding nursery. Increased mechanization was achieved by the acquisition of a highly satisfactory 7-coulter tractor-mounted drill developed by the National Institute of Agricultural Engineering, Silsoe, Bedfordshire, and the 'Thermaenius' type small plot thresher built by Messrs Garvie and Sons, Aberdeen, which made it possible to handle replicated trials of early generation segregates with a high degree of precision and maintainance of seed purity. This equipment should greatly facilitate the field testing work as well as enhancing the reliability of the yield data.

Agronomic studies with cereals (J.D.H., I.T.J.)

An experiment during the last two years has been concerned with the relative field performance of three varieties each of barley, wheat and oats grown at two locations and under three levels of nitrogen fertility. The more recently-introduced varieties in each species exhibited an improvement in yielding ability and also in the capacity of the crop to respond to higher levels of fertility without lodging, but the barley and wheat groups of varieties yielded more grain than the oats.

Although there was a greater number of seedlings established per unit area in the oat crop than in the barley and wheat crops, a larger number of tillers ultimately reached fruition in the barley crop. Barley also responded to increased nitrogen fertility by producing more fruitful tillers, whereas oats and wheat did not. On the other hand, increased dressings of nitrogen resulted in increased head weight in oats in particular, and under certain conditions also in wheat. Barley showed no response in head weight to increased nitrogen dressings under normal conditions.

The ability to produce a larger number of grain-bearing tillers per unit area is thus a most important aspect of a higher yield potential in the more recently introduced varieties of barley, although their average weight per head has been slightly reduced. Oat

varieties, on the other hand, do not possess the propensity for high fertile tiller production, and this would appear to be the most important limiting factor in the expression of high yield in the crop.

WINTER OATS

Weather conditions were ideal for the growing and harvesting of winter oats during the 1960-61 season, and as a result reliable yield data were obtained from field trials, also satisfactory data on disease reaction. Again no winter killing occurred to aid selection for winter hardiness.

Breeding (D.J.G., J.D.H.)

Favourable reports were received from the N.I.A.B. on the performance of the winter-hardy, mildew-resistant 5370 Cn 2/2/41, and the stem-eelworm resistant E.2297, and both varieties have now been officially recommended for release as new varieties. Limited supplies of Foundation Seed of the former, which is to be named Padarn (S.237), will be available for distribution in 1962 (description on p.181).

Two further winter oat segregates, 5370 Cn 18/2/41 and 5370 Cn 19/9/45, were included in the Preliminary Trials of the N.I.A.B. The latter outyielded S.147 by 22% and has thus been transferred to the Primary Trials for the coming season.

In the Station trials three further winter oat segregates possessing high quality grain gave very satisfactory yields over the last four seasons at Aberystwyth, and in small-scale plant breeder's trials at Seale-Hayne Agricultural College, Devon, and at Norfolk Agricultural Station, Sprowston, Norwich, as well as in a joint W.P.B.S./N.A.A.S. large scale field trial at Usk Farm Institute in 1960. A summary of the yields is as follows:

Relative yields of three winter oat segregates and controls in trials at Aberystwyth, Devon, Norfolk and Usk, from 1957/58 to 1960/61

Location	*Season*	*Controls*			*Segregates*		
		S.147	*S.172*	*Powys*	5686/19/13	5687/4/9/1	5687/3/7/31
Aberystwyth	1957/58	100	91	96	—	118	123
,,	1958/59	100	88	105	114	119	122
,,	1959/60	100	95	106	131	120	122
Devon	,,	100	104	116	—	104	110
Norfolk	,,	100	88	101	—	128	124
Usk	,,	100	108	104	—	121	—
Norfolk	1960/61	100	92	—	122	126	129
Aberystwyth	,, N_0	—	92	100	110	118	123
	,, N_1	—	91	100	117	129	131
	,, N_2	—	97	100	133	144	154

In view of the high yielding potential and grain quality of these segregates seed increase lots of each were grown for inclusion in the N.I.A.B. Preliminary Trials in the 1961/62 season.

Assessment of relative yields of winter oats when spring sown (D.J.G., J.D.H.)

When conditions are unsuitable for autumn sowing the question often asked by farmers is whether to sow winter oat seed in spring or purchase new seed of a true spring variety.

In contrast to some of the varieties of wheat and barley, winter oats do not require a cold period to induce heading, and consequently they can be sown in spring when conditions are unsuitable for autumn sowing. It is not known, however, whether they would yield as well as a spring type. To obtain an estimate of yielding ability when spring sown, two varieties of each type were sown at Gogerddan in mid-March, 1961. The relative yields were as follows:

Relative yields of varieties of winter and spring oats when sown mid-March. Sun II=100.

Variety	*Grain*	*Straw*
Spring oats		
Sun II	100.0	100.0
Condor	105.3	84.3
Winter oats		
Powys	89.0	70.6
Penrhyn	79.5	62.1

It would appear, therefore, that when winter oats have been purchased for autumn sowing and conditions have prevented this it is preferable to sow an adapted spring variety. If, however, the seed is that of a relatively early-maturing variety such as Powys there need not be more than a 10-15% reduction in final yield of grain compared with the better spring varieties, provided the sowing is done early. Sowing later maturing varieties such as Penrhyn, however, would be unadvisable.

SPRING OATS

The spring oat variety included in tests under Station No. V.2661 was officially approved in 1961 by the N.I.A.B. for multiplication, and will now be marketed as Maelor (S.236) (description on p.179).

Breeding for improved field characters (D.J.G., W.T.H.P., I.J.)

In the lowland breeding nursery 81 segregates were tested in a 9 × 9 Lattice layout. Of these, segregates from the 6290 Cn family (5045 Cn 48/2 × Sun II) proved to be the most promising in yielding ability and other field characters. Sister segregates from this cross also performed well in the Station's upland breeding nursery, and in the N.I.A.B./N.A.A.S./W.P.B.S. upland trials where the fertility had been appreciably raised. This indicates the possibility of developing varieties with a wide range of adaptation that will cover both upland and lowland conditions. Because of the promising performance of these selections under upland conditions, together with their satisfactory grain characteristics, it has been decided to withdraw 5405 Cn 2/2/44 (*Rep. Welsh Pl. Breed. Sta.* 1960, p. 44) from the upland series of tests.

Four black-grained segregates derived from the cross D.2973 × 01747/10/7 gave an average of 10% more grain than S.220, and if further tests confirm this improvement it is planned to replace S.220 with one of these selections for the poorer upland conditions.

Oat varieties for silage (D.J.G., J.D.H.)

Oats as a component of a mixture, or as a pure stand, are frequently grown for silage. In 1961 varieties and segregates which showed promise from this point of view were tested. After sowing in mid-March three silage cuts were taken on 2 June, 21 June and 12 July, corresponding to 'early silage', 'boot' and 'milky' stages. The results are:

Relative yield of dry matter from six varieties of oats cut for silage on different dates. Sun II=100

Variety	*Relative yield of dry matter on*		
	2 *June*	21 *June*	12 *July*
Sun II	100.0	100.0	100.0
Maelor	105.3	134.0	110.1
4749 Cn 1/9	110.1	113.5	108.1
D.2548	76.6	106.7	92.8
Penrhyn	78.3	113.2	88.2
S.147	78.9	95.1	88.6

The promising performance of Maelor and the segregate 4749 Cn 1/9 at the three cuts suggests that there is room for a variety developed specifically for silage production. Winter oat varieties sown in the spring although appearing to give a high yield of leaf at certain stages are not able to surpass a spring oat in yield of dry matter for silage at any stage. Further segregates have been selected which will be tested for this specific purpose.

Breeding for disease resistance (D.J.G., W.T.H.P.)

A severe infection of crown rust in south-west Wales during the season showed the value of crown rust resistance in Manod.

Relative grain yield and quality of Manod (resistant) and Condor (susceptible) with and without crown rust infection. Manod = 100.

Location	*Variety*	*Yield of grain**	*Grain quality*	
			Wt./1000 grain (gm.)	*Per cent husk*
1. No crown rust infection	Manod	100	34.6	25.8
	Condor	103	35.8	25.1
2. Severe crown rust infection	Manod	100	37.4	28.2
	Condor	76	28.1	33.8

*Yield data and the grain samples for analysis provided by Mr. E. I. Prytherch, Crop Husbandry Officer, N.A.A.S. (Wales).

This was clearly demonstrated in two N.A.A.S. trials in Pembrokeshire, the results of which are given on p. 61. Amongst varieties included in a large scale yield trial at two locations were Manod (resistant) and Condor (susceptible) to the crown rust infection. Crops at Location 1 did not have any crown rust infection, but in Location 2 a serious epidemic developed during early July which depressed the yield of Condor by no less than 27%, as well as affecting grain quality.

In the breeding nursery very efficient screening for crown rust was possible and resistance based on Ascencao, Landhafer and Victoria proved highly effective. In addition some of the promising lines of the 6290 Cn family which possessed the Bond type of resistance also sustained their high resistance.

A new source of resistance to mildew derived initially from *A. ludoviciana* Dur. was used in an extensive series of crosses in winter and spring oats using commercial varieties and the most promising segregate lines as parents. This new source of resistance has been introduced into the programme as a result of the appearance of biotypes in the glasshouse capable of attacking 01747/10/7 and Cc 4146.

Cytogenetic Studies (D.J.G., H.T., W.T.H.P.)

Hybrid plants obtained by backcrossing the synthetic amphiploids to a recurrent male *A. sativa* were similar in morphology to *A. sativa*, but again proved to be completely sterile when selfed. The sterility of the selfed hybrids indicates that such a backcrossing programme has its limitations as a method of introducing the desirable features of the diploid and tetraploid forms into the natural hexaploids. As a result of this experience it is intended to study the reciprocal cross, i.e. using *A. sativa* as the female parent, rather than as the male parent, as in the original cross. Attempts to make this cross, however, have so far been unsuccessful, mainly due to the low pollen fertility of the original amphiploids.

Colchicine-treated pentaploid forms derived from the cross *A. abyssinica* (4x) × *A. sativa* (6x) gave a number of fertile tillers and the chromosome complement of the plants grown from the resultant seeds will be examined during the coming year. Resistance to cereal root eelworm has been isolated in the diploid Cc 4659, and the tetraploid Cc 4660, and work was initiated to explore methods of transferring their resistance to the cultivated forms.

Spring barley (J.D.H., I.T.J.)

Twenty-five stiff-strawed varieties of barley of different straw lengths were tested in a small-scale yield trial at 2 levels of fertility. Yields were high throughout, and the response to nitrogen was marked. There was a 33% increase in yield of grain after a top dressing of 3 cwt./acre of Nitro-Chalk, but no variety × nitrogen interaction and no correlation between the length of straw of each variety and its final yield ($r = +0.083$). The most promising varieties from this trial are being used as recurrent parents in the backcrossing programme in order to introduce disease resistance into the barley crop.

In co-operation with Dr. J. G. Moseman, Plant Pathologist, U.S.D.A., Beltsville, a special powdery mildew nursery containing 170 entries was sown in the breeding block. A heavy attack of mildew in the field enabled an effective screening of mildew-resistant genotypes to be accomplished. In view of the large number of races of barley mildew which have been isolated, resistance factors from new sources were introduced into the programme to build resistance to as many races as possible into varieties adapted to British conditions.

Pooled families of 6th backcross hybrids of *Hordeum spontaneum* with Proctor and Rika as the recurrent parents were grown in the field. Susceptible segregates within each family were removed and head selections of the remaining resistant genotypes harvested. F_1 hybrids were produced from Proctor and Rika crossed to a wide range of parents carrying resistance to cereal root eelworm (*Heterodera avenae*), scald (*Rhynchosporium secalis*) and Barley Yellow Dwarf Virus.

Six-rowed segregates derived from crosses involving 2-rowed (Herta and Domen) and 6-rowed forms (Prefect and Cb 740) have not in general yielded segregates with stiffness of straw equal to the 2-rowed parent, or with the desirable uniformity of grain. The most satisfactory segregates showing a combination of stiff straw and relatively uniform grain samples have been retained for further observation before testing for yield.

F_2 bulk populations of the 45 crosses derived from the 10 parent diallel (C399b) were grown as unreplicated seed-increase plots during the year to provide sufficient seed for replicated yield trials

in 1962. Head selections were also taken from each population for head-row plots in the coming year.

Six families each containing 800 F_2 plants were grown in a birdproof cage to detect and estimate the linkage of the *Ddt* gene with various genetic markers. No obvious linkage of the *Ddt* gene with any other markers has yet been detected, therefore a more detailed analysis of the F_3 progeny will be undertaken in 1962.

SPRING WHEAT

Breeding for improved field characters (D.J.G., H.T.)

Several F_4 lines were selected from crosses between Peko, Miana, Svenno, Koga II and Station Selection No. 2 and grown as single drill plots for initial yield estimates. The group of lines derived from the cross Koga II × Svenno represented the lowest mean for families but the highest variance of all the crosses studied. The cross Koga II × Sel. No. 2, on the other hand, gave the highest mean value but a relatively low variance. It is of interest that in a replicated trial containing lines selected in the F_3 generation for their field appearance, the highest yielding group of selections was obtained from both these two crosses. In this preliminary trial five selections gave grain yields significantly higher than Koga II, and these are being continued for further test.

FORAGE RYE

Preliminary yield trials (J.D.H.)

Lines which have gone through three cycles of selection for improved tillering capacity, response to early spring dressings of nitrogen and ability to grow at low temperatures have been extracted for further observation. A bulk population made up of the most promising lines was forwarded to the N.I.A.B. for initial testing in autumn 1961. Preliminary tests during the spring with selected populations indicated that the selections were decidedly superior in forage production to the control variety Lovazpatonai. It was not clear from these results, however, whether this superiority

was due entirely to the genetic potential of the selected lines as the seed used for the control had been imported from the Continent, whilst the seed of the selected lines had been grown at the Station. In 1961 isolation plots of the Continental control varieties were grown at the Station so that in all future trials seed of controls and selected lines will have been produced under the same conditions.

MAIZE FOR SILAGE

Preliminary trials (D.J.G., T.D.J.)

The year 1961 was not ideal for the maize crop in Wales because of dry weather after sowing and subsequent cool, moist conditions during maturation of the crop. Nevertheless, some varieties under test at the Station yielded in the region of 20 tons/acre fresh material when harvested on 16 October.

The trial consisted of plots of a number of varieties from America and Europe mostly of the medium-early and medium maturity groups. The results, though from unreplicated trial, are interesting in that they emphasize the necessity of choosing sufficiently early maturing types for each locality. With grain development there is a very rapid accumulation of dry matter and the relative contribution of cob to total dry matter production increases markedly, as illustrated in the following table.

Variety	*Maturity*†	*Total fresh yield (tons/ac.)*	*Total dry matter yield (cwt./ac.)*	*Percentage dry matter*	
				Cobs	*Yield due to cobs*
Orla 266	4.3	19.6	81.8	26.0	51.4
Inra 244	3.8	20.4	77.7	24.8	50.6
Caldera 402	3.5	17.9	69.9	20.2	47.4
Pioneer 395	3.1	18.9	73.7	17.6	38.4
Giant Hybrid	2.1	16.5	56.2	14.4	28.5

†Based on an arbitrary classification: 0=tassel first exserted;
6=mature grain

A high percentage of dry matter in the cob is important because it represents a valuable accumulation of starch equivalent, and also it ensures more satisfactory silage formation with less effluent losses.

FIELD BEANS

During the year under review problems in bean breeding were mainly concerned with selection for self-fertility and the evaluation of synthetic varieties.

Self-fertility (H.T.)

Progress in selecting for self-fertility in British commercial stocks has been slow. Four generations of selection for self-fertility in a population of Tick bean has not yielded any highly self-fertile, self-tripping lines, although a few showing some promise have been isolated. On the other hand, screening varieties of foreign origin, in particular from the Mediterranean area, resulted in the isolation of lines which had decidedly superior self-fertility. In 1959 one of these, Ch 182, was crossed with an inbred line established from Tick (Line A), and in 1961 the F_1, F_2 and F_3 generations were grown in a bee-proof glasshouse to assess their self-fertility. The results are given below.

Mean self-fertility of F_1, F_2 and F_3 generations of a cross between Ch 182 and an inbred line derived from Tick bean

Generation	*No. of flowers/plant*	*Per cent flowers forming pods*	*No. of seeds/plant*	*No. of sterile plants*
F_1	46.7	91.2	122.4	0
F_2	28.9	42.4	25.2	7
F_3	37.7	39.4	27.7	0

There was a marked depression in self-fertility in the F_2 and F_3 generations compared with the F_1.

In the F_2 generation of the cross Inbred Tick × Inbred Tick the mean number of seeds/plant was 7.24 compared with 25.2 in the F_2 generation of Ch182 × Line A. The frequency of plants having the higher number of seeds/plant was much greater in the Ch 182 × Line A F_2 generation. Furthermore, there was no observable reduction of self-fertility in the F_3 generation, compared with the F_2 generation. It may be concluded, therefore, that this cross offers distinct possibilities for the selection of lines possessing a higher degree of self-fertility than has hitherto been found in British stocks of beans. Some of the progenies with higher flower numbers in the F_3 showing

a high degree of self-fertility have already been isolated for further selection work, and it is proposed to compare the performance of these lines under both bee-proof and field conditions in 1962.

Synthetic varieties (H.T.)

A number of lines have been progeny-tested, using the top-cross and polycross techniques. On the basis of their superior performance in the progeny tests eight lines were mixed in seven different combinations to form the following synthetic populations.

Synthetic population No.	*Component line combinations*
12	1 and 2
13	1, 2 and 3
14	1, 2, 3, and 4
15	1, 2, 3, 4, and 5
16	1, 2, 3, 4, 5, and 6
17	1, 2, 3, 4, 5, 6, and 7
18	1, 2, 3, 4, 5, 6, 7, and 8

These synthetics were first compounded in 1959 by mixing equal proportions by weight of the component lines, and growing them in 1959 in isolation plots for inter-pollination. The seed harvested from these plots was again grown in isolation plots in 1960 to produce the second generation seed. In 1961 a yield trial was set up of the eight original lines, together with the first and second generations of the 7 synthetic varieties to assess the best line combinations, and the relationship between the yielding capacity of the synthetic varieties and the component lines.

The yields of the component lines and the first and second generation synthetic varieties were as follows:

Yield of grain per plot (gm.)

Individual lines		*Synthetics*		
Component line No.	*Yield (gm.)*	*Synthetic No.*	*Generations*	
			First	*Second*
1	2975	12	2875	2200
2	2700	13	2205	2270
3	2805	14	3170	2735
4	3835	15	2870	2760
5	2565	16	2305	1990
6	2180	17	2340	1965
7	3065	18	2590	1620
8	2765			
Mean	—		2622	2220

L.S.D. (P=0.05) = ±571.4

It will be observed that none of the synthetic lines outyielded the highest individual line (No. 4), and that the yields of the second generation synthetic varieties were generally lower than those of the first generation.

In order to assay the relationship between the yielding capacity of the synthetic varieties and the component lines, the mean yield of all the component lines in a particular synthetic variety was calculated. The correlation between the calculated mean value and the actual yield of the first generation of the synthetic varieties was high ($r = +0.8017$). On the other hand, the correlation between the mean value and the second generation of the synthetics was low ($r = +0.2727$). It may thus be concluded from the results that populations synthesized for purposes of this investigation did not manifest the heterosis observed in a truly hybrid population. Unless a reliable control of cross-pollination can be achieved through the use of male sterility, or other factors, in order to ensure a higher degree of hybridity than that attained under field conditions, this method of approach seems unlikely to make a permanent improvement in bean crops.

General breeding (H.T.)

Lines of early-maturing spring beans were put into seed increase plots in 1961 for inclusion in a yield test in 1962.

Selection for uniformity of maturity on the stem has also been undertaken. A few selections which show a clustering of pods on a small number of fruiting nodes are being multiplied for future yield trials.

Tests with the two winter bean selections, Ch 271 and Ch 29/10, were continued by the N.I.A.B. in 1960/61, and the yields of both selections were found to be equal to the control variety used.

BRASSICAE CROPS

Continued progress was made in the routine breeding programme for the improvement of the agricultural kales. An important aspect of the improvement programme is winter hardiness but the past few winters have been insufficiently severe at Gogerddan for useful assessment of hardiness. More consistently severe conditions have been experienced at the nearby hill centres and consequently much of the material for selection is now grown at that centre.

Intervarietal hybrids (T.D.J.)

The segregation of F_2 material of the cross Canson kale × kohlrabi has produced some interesting morphological types with a short bulbous stem, highly branched and with a dense crown of leaves about 10″ to 15″ high when grown as spaced plants. Such a type if winter hardy could be valuable for sheep grazing late in the season.

Mass selection in marrow-stem kale (T.D.J.)

Randomly-selected plants from one commercial stock of marrow-stem kale seed were inbred and the I_1 progenies used as a basis for selection. Plants selected for each of the 3 categories short, medium and tall were grown in isolation plots. Twelve progenies from each plant were studied and mean progeny heights measured after 3 months' growth. The results are shown in the table:

Mean progeny height (in.)

Short	*Medium*	*Tall*
4.4	7.3	12.7
6.3	7.6	12.9
6.8	7.7	13.4
7.1	8.3	13.8
7.1	9.5	14.9
7.1	9.6	15.0
7.4	9.7	16.0
7.4	9.9	17.7
7.6	9.9	—
7.9	10.6	—
—	10.8	—
—	11.3	—
—	11.7	—
—	12.3	—
—	12.5	—
Mean 6.9	9.9	14.5

Overall means respectively for the short, medium and tall isolations were 6.9″, 9.9″ and 14.5″ showing that 100% differences in mean population height were achieved after only one generation of selection. This illustrates the large genetic variability, at least for the character chosen, in the stock of marrow-stem kale selected for investigation, and in addition indicates the efficiency of the screening technique based on a generation of inbreeding before selection.

Induction of new polyploids (T.D.J.)

Two main approaches are possible in the use of polyploidy for *Brassicae* improvement. These are, firstly, the synthesis of artificial amphiploids and, secondly autopolyploidy. Both approaches are under investigation, the former because it offers a means of introducing new variability into rape (*B. napus* $2n = 38$) and the latter because autopolyploids can be expected *a priori* to be useful in *B. oleracea* where the basic chromosome number is low ($2n = 18$) and maximal vegetative production is of prime importance.

The production of tetraploids by application of 1.0% colchicine solution to growing points of very young seedlings is relatively easy and seed production from autotetraploid plants has been found to be good. Some second and third generation tetraploids of marrow-stem kale and Canson kale grown in the field have shown no evidence of a striking increase in vegetative vigour. The marrow-stem tetraploids appear to have very soft succulent stems which may be an advantage, but the tetraploid forms of Canson are generally less branched than the diploids. Nevertheless, numerous generations of selection on a wide range of tetraploids will be necessary before firm conclusions can be drawn as to their potential for the farmer.

RAPE

Disease assumes a much greater importance in the rape breeding programme than it does in the kales. The *B. napus* types, including the swede, are very susceptible to mildew (*Erysiphe polygoni*) and clubroot (*Plasmodiophora brassicae*). Control of these by breeding should prove to be a very important improvement in these crops. Mildew is particularly severe on early sown crops and in hot seasons, and it is one of the main factors limiting the earliness

of sowing swedes. Clubroot, on the other hand, being soil borne is more localised in distribution, nevertheless it is sufficiently widespread to be of major importance. Efforts are being made to introduce resistance to both pathogens in the *B. napus* breeding programme.

Yield potentiality of different *B. napus* varieties (T.D.J.)

In a trial to compare yields of giant rape, dwarf rape, hungry gap kale, rape-kale and asparagus kale sown in July and harvested in November it was found that the yields of the giant rape were generally higher than other varieties. However, yields of leaf alone were also assessed and it was then found that the giant rapes were not consistently better than the dwarf rapes or hungry-gap kales. The yields are given below as a percentage of a giant rape control in respect of total yield and yield of leaf.

Relative fresh yields of rape types

Variety	*Stock*	*Yield of*	
		Whole plant	*Leaf only*
Giant rape	(a)	100	100
	(b)	93.4	98.0
	(c)	85.6	95.9
	(d)	73.3	87.1
	(e)	90.4	91.0
Dwarf rape	(a)	87.8	105.4
	(b)	80.7	85.7
Hungry-gap kale	(a)	84.0	90.9
	(b)	90.0	104.7
	(c)	81.0	88.9
Asparagus kale		63.7	87.5
Rape-kale		56.0	75.6
L.S.D.		±9.8	±13.4

Grazing a rape crop *in situ* usually results in very high utilization of the leaf fraction but only a small amount of stem is eaten. It can be seen from the relative yields in the table on p. 71 that erroneous conclusions regarding the merits of varieties can easily be reached if leaf yield itself is not estimated. The breeding of new types should be based on leafiness without reference to stem yields except insofar as breeding for a particular plant height may be advantageous.

GRASSLAND AGRONOMY

Ll. Iorwerth Jones

Herbage variety evaluation (D.G.M., I.G.W., R.J.K.W.)

Assessment of the agronomic behaviour and production of potential herbage varieties continues to form an important part of the routine work of the Section. Past experience and recent experimental work has shown the undesirability of assessing the production of herbage species wholly on a system of continuous mowing with application of inorganic fertilizers, in lieu of rotational grazing and the normal return of animal droppings. A scheme for the evaluation of herbage varieties must include provision for the conditioning of the sward by the grazing animal and, in addition, a range of managements that will not only allow sound conclusions to be drawn regarding the comparative nature of the material tested, but will also indicate the conditions most favourable for full exploitation in agricultural practice.

During the year a comprehensive trial designed to compare the production and behaviour of two potential varieties of perennial ryegrass with four established varieties was concluded after four years of study. The trial was sown in April 1957 on lowland soil of moderate fertility under a cereal crop which was cut for silage in mid-June. The ryegrasses were sown at the uniform rate of 20 lb./acre with 2 lb./acre S.100 white clover. Annual dressings of 3 cwt./acre 12:12:18 compound fertilizer were applied in autumn and 3 cwt./acre 15% Nitro-Chalk in spring. Nine systems of management were imposed comprising all combinations of three dates of autumn resting, 1 August, 1 September and 15 October, with three dates of winter grazing, 1 December, 1 February and 10 March. During the growing season all treatments were grazed in rotation and a silage cut taken in June.

Data collected from this trial form the basis of the agronomic description of the newly released perennial ryegrass variety S.321, (p. 177).

Spring growth potential of this new variety was significantly better than that of S.23. Relative yields at the end of April in four seasons and under all treatments were S.23 = 100, and S.321 = 110, with the superiority of S.321 varying from 4% in an early spring to 20% in a cold, late spring.

Other equally comprehensive trials still in progress form the basis of the agronomic description of S.341 cocksfoot (p. 178), and S.352 timothy (p. 179).

S.341 begins active growth in spring about three weeks earlier than S.37 or Danish. Yields obtained in the trials are summarized as follows:

	Dry matter yield (lb./acre) on		
	20 *March*	3 *April*	8 *April*
S. 341	1200	1700	1900
S.37	900	1100	1400
Danish	750	1050	1250

If full use is made of the early growth potential of S.341 its performance during the following summer will tend to be inferior to that of later varieties. If, however, it is not grazed but allowed to make uninterrupted growth to the hay stage, early and equally heavy crops of hay are produced:

Hay cut 14 *June*: *dry matter yield* (*lb./acre*)

	*S.*341	*S.*37	*Danish*
After grazing in early April	2800	3800	3400
After resting from February	6500	6500	6400

In early spring, and until mid-April, S.51 is more productive than S.352. Later in the season the advantage is significantly in favour of S.352, as shown in the relative yields (dry matter):

	Late April	*Mid-May*	*Early June*
S.51	100	100	100
S.352	100	112	124

Tetraploid ryegrass. Three tetraploid varieties of perennial ryegrass, with one Italian ryegrass and one Westernwolth ryegrass all of Dutch breeding, were planted in swards with S.100 white clover in May 1960, together with a number of established diploid varieties.

The three tetraploid perennials designated respectively Early Hay, Late Hay and Late Leafy established well, and by mid-August had produced good silage crops of nearly 6,000 lb./acre dry matter,

very similar to the production from S.24 ryegrass swards. The tetraploid varieties appeared more bulky and at all times were a darker green than the diploids, but differences in dry matter production were small. Growth during the autumn was slightly better in the tetraploid varieties, and the proportion of white clover in the swards was higher in comparison with the diploids. During early spring in the first harvest year the Early Hay tetraploid was more productive than the other two but was not superior to S.24. The heaviest yield of hay in mid-June, after spring grazing, was given by the Late Hay tetraploid; subsequently there were no differences in productivity.

The tetraploid Italian ryegrass was inferior to S.22 and markedly poorer than the Danish variety Hinderupgaard in the seeding year. It was again slightly inferior in the spring of the first harvest year. During the summer of that year, however, its relative performance improved, and, as in the case of the perennial ryegrass tetraploids, the clover content of the sward increased considerably.

Mommersteeg's Westernwolth (diploid) showed better vigour than the tetraploid variety during the establishment period, but production from both subsequently was very similar.

Our experience of the tetraploid varieties tested has been that although they appear to be more vigorous at most times, their productive capacity in terms of dry matter is no better than that of diploids. The tendency to a somewhat poorer performance during establishment may be caused by the larger size of the seed of which fewer were sown, resulting in thinner stands. The lower tillering nature of the tetraploids is reflected in much higher clover contents of the swards.

Extra mural investigations. Advantage was taken of the opportunity to conduct further investigations of a more extensive nature on commercial farms. Two trials were set-up, one to compare S.321 with S.23 and Melle pasture ryegrasses under fairly heavy sheep grazing and the other to investigate the potentialities of S.170 tall fescue, a bred variety of meadow foxtail Bh 284, and a number of other grasses on strong silt land liable to frequent flooding.

Clover agronomy. In conjunction with the Herbage Legume Breeding Section, a number of trials are being conducted to investigate the agronomic behaviour of diploid and tetraploid varieties and ecotypes of red and white clovers. Two current investiga-

tions are concerned with the effect of mineral fertilizers, particularly potash, and of various systems of defoliation on the yield and persistency of some varieties of red clover.

It has been noted from these and other trials in which varieties of red clover have been included, that very high yields of herbage can be obtained when management and manuring combine to allow optimum development of the legume. In 1960 and 1961, first year stands of S.352 and three varieties of red clover, gave yields equivalent to 5 tons of hay/acre early in June without any applied nitrogenous fertilizers.

Herbage digestibility (D.G.M.)

There has always been the need for methods of evaluating herbage varieties to be as comprehensive as possible. An important link in this chain is a practicable and reliable method of determining the nutritive value of the material under consideration. The experience of workers at other research centres indicates that the digestibility of herbages at the same stage of maturity is the best single measure of their comparative feeding value.

The establishment at this Station of a small animal nutrition unit with a refrigerated store for herbage has made possible the inception of a programme of digestibility determination of herbage samples. The limited amount of data collected to date agrees with the findings of other workers, notably Raymond at Hurley, and can be summarized as follows: (a) The digestibility of herbage remains fairly constant until ear emergence, after which it falls rapidly, and (b) The digestibility of ryegrass is always higher than that of cocksfoot at a similar stage of maturity.

Whereas the determination of digestibility in the standard way is feasible and reliable for established varieties, it is not a practicable method of dealing with a large number of samples of breeder's material available only in small quantities. Methods of *in vitro* digestion can be used on small amounts of herbage on a laboratory scale and are proving sufficiently closely correlated with *in vivo* determinations to form an efficient screening technique for breeder's material and new introductions. The unit provides the Chemistry Section with the necessary facilities for the conduct of these laboratory tests.

During the year a trial has been set up in collaboration with the Plant Breeding Institute, Cambridge, and the Grassland Research Institute, Hurley, to assess the agronomic behaviour of two synthetic varieties of tall fescue developed at Cambridge. A large number of grass varieties from trade sources have been included in sowings made for observational purposes.

Three small trials have been sown in collaboration with the Chemistry Section, to provide material for the study of herbage composition in the laboratory.

In addition, projects have been started in collaboration with Grass Breeding and Developmental Genetics to develop techniques for the agronomic assessment of breeder's material.

Establishment studies (A.H.C.)

The establishment of productive leys is of paramount importance to agricultural production, and in recent years a series of trials has been conducted to study some of the problems still outstanding in sward establishment.

The effect of undersowing on the cereal cover crop. Most grass and clover mixtures in Britain, particularly in arable areas, are sown under a cereal cover to obtain a grain crop and an established sward in the same year. Investigations have shown that undersown herbage influences the growth, yield and quality of the cereal. For example, in oats the number of fertile tillers was reduced, and quick-growing grasses did this more effectively than clovers, particularly when nitrogen was applied. The yield of straw and the nitrogen content of straw and grain were also reduced and the difficulty of harvesting increased. When undersown only a small fraction of the nitrogen was recovered through the cereal.

Production from leys in the year of sowing. One of the main arguments in favour of using a cover crop is that the cereal is said to cover the cost of establishment. This presumes that production from herbage seeds sown without a cover crop is low. Data (Charles 1961, *Herb. Abstr.* 31, 1-6) obtained on the yield of a range of mixtures in various parts of the country, showed that in practice a rapidly-developing grass/clover mixture can produce as much starch and protein as an average crop of oats plus the undersown herbage. When cereal yields were high, however, the cover crop increased the total production. Although using a cover crop for grazing or silage increased production early in the seeding year,

the mid-season yield in July and August was reduced, and in farm practice this is the time when production from maiden seeds is particularly useful.

The proportion of sown species that establish. The ratio of legume to grass is an important consideration, and the method of establishment has a marked effect on this. The cover crop increased the ratio of red clover to grass, and frequent grazing depressed the red clover and increased the white clover. This is illustrated by the following figures based on swards which had not received nitrogen.

	Percentage of clover in the herbage in mid-August of the seeding year		
	No cover crop		*Cover crop harvested for grain*
	Frequent grazing	*Infrequent defoliation*	
Red clover	16.6	29.3	40.6
White clover	6.7	0.6	1.0

The practice of applying nitrogen to cereals is increasing, and it is not surprising that arable farmers are finding it more difficult to establish clover in undersown leys. Apart from the greater competition to herbage generally by the heavier cereal crops when nitrogen is applied, the clover is depressed more than the grass by the application of the fertilizer. The increasing use of nitrogen and of the higher yielding cereal varieties may well cause a break with the tradition of undersowing.

Effect of method of establishment on yield in the following year. In addition to occasional failures due to the cover crop the method of establishment affected the productivity of the sward for a considerable time. The main effects of treatments applied in the year of sowing are often those which influence the establishment of red and white clovers. Under a management where nitrogen is not applied in the first harvest year the treatments which favoured the growth of the legume during the seeding year result in the higher yields in the first harvest year. In the ryegrass mixtures studied this difference was considerable, being up to one ton/acre of conserved forage.

Selection in swards (A.H.C.)

Grass varieties are composed of a mixture of genotypes, and agronomic selection processes, soil or climate may operate to change the variety. Mixtures of cultivars with distinct plant types within *Lolium*, *Dactylis* and *Phleum* have been studied so that the processes of selection in swards could be followed. In these investigations a rapid reduction in plant number occurred during establishment. Two months after sowing the surviving grass seedlings represented about 20% of the viable seed sown, whereas less than one year after sowing the number was about 10%. Samples taken from swards managed in various ways showed that this differential survival was not purely random, but was a response to the agronomic selection processes applied by management and manuring. These selection processes operated in a very short space of time, and in *Dactylis* a cover crop reduced the proportion of early-flowering hay types 8 weeks after sowing. Data from older swards show that differential survival can result in further marked changes in the population of established grassland.

Hill reseeding (LL.I.J.)

Investigations regarding the establishment of grass and clover seeds on a number of hill centres following a liberal application of lime or slag to the soil have shown that:

(a) in the absence of cultivation the take of grass and clover was very poor at the best centres and a complete failure at others ;

(b) the destruction of the herbage by chemicals prior to sowing markedly increased the number and size of established plants even in the absence of cultivation after sowing ;

(c) the number of established plants and their vigour of growth were far superior on land which had been rotary-cultivated than on areas subjected to chemical treatment ;

(d) chemical treatment followed by rotary cultivation showed little improvement over rotary cultivation alone ;

(e) the best plant establishment was obtained after ploughing and harrowing, although the vigour of growth of the plants in the seeding year was slightly lower than on the rotary-cultivated areas.

The improvement of herbage varieties for hill reseeding. (R.H., J.M.M.M.)

At the present time, varieties recommended for the reseeding of hill and upland areas are mostly grasses and legumes that have evolved in a lowland environment. They have been selected by natural forces and by breeding for maximum productivity under conditions of high fertility and relatively strict management control. As a result the degree of success which attends the use of such varieties as S.23 perennial ryegrass and S.184 white clover depends on the ease with which these husbandry requirements can be effectively enforced in the new environment.

Reseeding is only one aspect of improving hill land and must be considered along with other practices such as more adequate stock control, increased top-dressing and surface treatment of the native vegetation. It does represent, however, the most effective method of increasing both the quality, quantity and seasonal distribution pattern of the available herbage which are essential prerequisites to increasing overall stock-carrying capacity. A programme has, therefore, been commenced to investigate the implications of breeding new varieties for the specific requirements of Britain's hill areas.

At the planning stage several considerations were pre-eminent. There is the need to characterize the environment itself, particularly with regard to climatic and soil factors. Information of this nature is at best fragmentary and requires expansion in order to assist in the development of models for use in the breeding nursery and to make full use of controlled environment studies. While more is known about the herbage plant itself, provision has also to be made for further critical study of the agronomy and certain physiological aspects of species and varieties that have already shown potential.

The hill environment perhaps more than any other cannot be treated as a single entity. Each variety must be considered in several possible situations in an integrated ecosystem. Certain types will be required to provide herbage for spring and autumn keep and possible conservation on the lower hill; others will be used

at higher altitudes and will have their value in a 'plateau' form of production requiring only limited management and fertilizer input for maintenance.

The studies have been developed to take account of these minimal requirements and will eventually lead to the expansion of breeding on a basis of the efficient utilization of limited nutrients rather than maximum productivity. The importance of the legume on the hill must be considered at this point and observations are being made on the contribution of several species, more particularly white clover, in order to evaluate the substance of the faith placed in this component.

The final consideration, and perhaps the most important, is the need to provide potential breeding material by conditioning a wide range of species and varieties to the hill environment through the process of controlled natural selection.

The first phase of the programme started in 1961 when a series of experiments were sown in early summer on three contrasting sites made available to the Station. The areas, although small in extent, give a useful contrast of climatic and soil types and form an ecological succession:

(a) Pwllpeiran (1300 ft.), a *Festuca-Agrostis* community on a well drained brown earth,

(b) Syfydrin (1100 ft.), a *Nardus*-dominant community with variable proportions of *Molinia* on a peaty gleyed podsol,

(c) Blaenmyherin (1600 ft.) a *Calluna-Eriophorum-Sphagnum* community on undrained deep peat.

Characterization of the environment. A definition of the environment in each area was considered essential and at the outset an examination was made of the floristic composition of the vegetation and the profile and chemical status of the soil. From Syfydrin, continuous recordings of the microclimate in terms of temperature, rainfall, evapo-transpiration and soil moisture will provide essential information for the correlation of controlled environment studies with actual hill conditions. In the first season, for instance, an assessment will be made of the temperature tolerance and growth rhythms of 10 varieties concurrently being studied in controlled

environments by Dr. J. P. Cooper (Developmental Genetics), p. 16. These include 4 ryegrasses, 4 cocksfoots (including a Mediterranean-type diploid), S.170 tall fescue and sweet vernal.

Agronomy studies on selected species. Useful information on the performance of various grass species in the hills has been acquired at Aberystwyth, and by various workers in other parts of Britain. Basic knowledge is far from complete, however, especially about the less widely used types. For this reason, four such grasses were chosen for more detailed studies, bent (*Agrostis tenuis*), smooth-stalked meadow grass (*Poa pratensis*), red fescue (*Festuca rubra*) and tall fescue (*Festuca arundinacea*).

Each shows potential in a different sector of the environment. Bent is the dominant species in natural hill pastures at the upper end of the ecological range and as such is an obvious choice for further study. Under certain conditions it is often slow to establish but ultimately forms a dense sward which is resistant to invasion by regenerating species. Unfortunately, it also restricts the growth of clover and any other sown elements. Its general growth rhythm is unsatisfactory and improvement is required both late and early in the growing season.

Smooth-stalked meadow grass is indigenous to the hills and is found where soil nitrogen concentration is high, for example, on stock camps and shelters. It is an intriguing possibility, therefore, that this grass might represent an ideal type for reseeding. It is one which could form the basis of a sward with minimal maintenance requirements and yet retain the ability to respond to intensification of management in order to produce herbage for specific purposes. Again, however, initial growth vigour is poor, and even the best of the existing varieties are greatly inferior in production to S.23 ryegrass.

Red fescue is indigenous on the better class hill soils. When used in reseeding, S.59, for example, shows a wide range of adaptability and because of its tolerance to continuous sheep grazing could form the basic component of mixtures for the improvement of poorer areas. When under-utilized it produces a profusion of flowering stems, and when matted, clover disappears from the sward, while at the same time the herbage becomes less palatable.

In each instance one of the major agronomic problems is low initial sward vigour and production, and it is against this background that the association of three companion grasses of different competitive thresholds is being analysed, i.e., S.22 Italian ryegrass,

S.48 timothy and S.37 cocksfoot. The productivity of these in mixtures with S.184 white clover is being compared with that of S.23 ryegrass and S.50 timothy following limited fertilizer applications under three lime regimes.

Considerable importance must be attached to the possibility of introducing and maintaining a sward on the hill which will provide annually much earlier spring growth than is now possible. Tall fescue has demonstrated a great potential in this role in experiments on various hill areas in Scotland. One of the important drawbacks, however, is the need to provide a much denser sward early in its history; for this reason, additional comparisons are being made between normal and heavy seed rates (35 lb. and 50 lb./acre) S.170 tall fescue.

When facilities permit the extension of these studies, Yorkshire fog will be given a high priority rating. At the same time, bearing in mind the value of S.23 ryegrass particularly in the west, studies of perennial ryegrass will continue, especially regarding variation in the species that might lead to the selection of plants more tolerant of lower pH status and fertility.

The place of clover on the hill (in collaboration with Mr. D. Gareth Jones and Mr. W. Ellis Davies, Herbage Legume Breeding). There is little factual information on the agronomy and function of white clover under those very conditions where it is claimed to be indispensable. Before an objective appraisal can be made of the need to breed clover varieties for the hill, it is necessary to study the actual role of clover in developing a nitrogen cycle. As a consequence, preliminary investigations are being concentrated on grass/clover relationships, and the efficiency of nitrogen fixation, using *Rhizobium* inoculations developed at the Station. Both S.100 and S.184 white clovers are being examined with four contrasting associated grasses, S.23 perennial ryegrass, S.48 timothy, S.59 red fescue and S.143 cocksfoot, and the production under these varied levels of competition and interaction is compared with that derived from mineral fertilizers under three levels of lime application.

The conditioning of breeding material and the examination of new introductions. In the main grassland agronomy studies provision has been made for the ultimate selection of plants which have been conditioned and exposed to natural selection under various regimes of competition, management and nutrient status. Experience and data from these areas will be used to extend work of this nature.

Introductions will in future feature more prominently in the research programme, and the limited studies at present being undertaken with *Poa pratensis* and tall fescue types will be expanded if necessary.

Reference plots. A collection of 20 species, including 32 grass and 10 legume varieties, has been established in small plots at Syfydrin. Some have little, if any, potential for hill reseeding but will prove invaluable in an examination of the factors governing survival and failure. Those of higher potential will, of course, provide data of more direct use.

The areas described were sown down between mid-June and early July. During the early establishment period conditions were mainly favourable but the hazards of the hill environment soon became apparent in the form of excessive drying winds at Pwllpeiran, soil erosion at Syfydrin and patches of excessive wetness at Blaenmyherin. Generally the plot casualties were at a minimum and the overall position is very satisfactory.

At Syfydrin in particular, all four species in the main trials show a higher-than-normal vigour of establishment, and, except for tall fescue, this had led to an above-average early ground cover. *Agrostis tenuis* is outstanding in this respect and is the only species which compares in density with S.50 timothy. Where companion grasses have been sown there are already marked interactions between species, companion grasses and lime level.

In the clover trials the grasses established with far greater density on the waterlogged Blaenmyherin site than at Pwllpeiran. Under these conditions at Blaenmyherin it did not produce the same growth rate, and it was possible to graze only once before winter, compared with twice at Pwllpeiran. The outstanding feature was the startling response to inoculation seen on the deep peat in terms of clover establishment and plant size. No similar response was apparent on the brown earth. Further details of this are reported by the Herbage Legume Section, p.

Seed coating (LL.I.J.)

A readily available supply of nutrients is essential for the rapid establishment and the vigorous initial growth of seedlings. Hill soils are very low in plant nutrients, and to ensure a take of seeds, particularly of white clover, it is essential to apply heavy dressings of

lime and phosphate. It has been suggested that a supply of nutrients on the outside of the seed coat might improve the establishment of the seedlings under the present recommended rate of fertilizer application to the soil. It might ensure a satisfactory take with lighter dressings of fertilizer even under surface sowing when the new seeds have to compete with the native species. These preliminary investigations have been concerned with seed germination, establishment and growth on cultivated soil *in situ* on the hills and in boxes under glasshouse conditions.

Coating the seeds with ground limestone and/or basic slag had no adverse effect on germination. The germination of white clover was reduced by 10% to 15% when superphosphate was used, and by 50% when the seed was coated with a soluble concentrated fertilizer, a treatment which resulted in a complete failure of germination of rape seed. A coating of various fertilizers and/or lime had no significant influence on the initial growth of the rape seedlings or on their subsequent development at two field centres, a lowland and a semi-upland ploughed field, to which the usual fertilizers had been applied. A similar result was obtained for oats when the grain coated with fertilizers was sown in a lowland field.

The most interesting results concerned the establishment, overwintering, vigour of growth and nodulation of white clover. Results from sowings *in situ* in the hills and in hill soil under glasshouse conditions show that the initial growth of seedlings from white clover seeds coated with lime and/or fertilizers was generally more vigorous than seedlings from untreated seed grown on upland soil previously uncultivated and unfertilized, irrespective of the fertilizer applied to the seed-bed. During later stages of growth, particularly after the first winter, coating the seed with lime had no significant influence on the size of the plants or vigour of growth.

White clover sown on upland areas on 31 July 1958 suffered heavy casualties during the following winter, but there were fewer casualties amongst plants developed from seeds which had been coated with ground limestone. The lower casualty figures were observed for all soil fertilizer treatments except where ground limestone had been applied at the rate of 2 tons/acre in the seed-bed. Most of the casualties occurred amongst the smaller and underdeveloped plants, and the data suggest that the more vigorous initial growth of the seedlings from lime-coated seeds enabled the young plants to become well established before the onset of the rigorous winter conditions.

Apart from influencing the initial growth of the clover, coating the seed with ground limestone and/or basic slag increased nodulation. On a variety of hill soils the application of ground limestone and/or basic slag to the seed-bed under glasshouse conditions improved the establishment, growth and nodulation of the clover plants. When used as coatings on seeds, establishment and initial growth were improved, but the most striking effect of seed coating was the enormous increase in plant nodulation which was obtained on unfertilized soils, as well as a substantial increase even where fertilizers had been applied.

This is illustrated by the following table:

	Ground limestone and/or basic slag applied			
	None	*On seed coat*	*In seed-bed*	*On seed coat and in seed-bed*
Percent establishment of white clover seed	57	71	73	71
Weight of clover plants 6 weeks after sowing (mgm. dry matter)	2.6	5.0	21.0	28.5
Percent of clover plants nodulated	2	58	62	77

Growth rate studies in perennial ryegrass (A.G.D.)

During the past year Miss Alison Davies was a guest research worker in the phytotron of the Institute for Biological and Chemical Research of Field Crops and Herbage at Wageningen, the Netherlands. The work carried out was primarily concerned with the growth rate of different varieties of perennial ryegrass under standard conditions to assess the principal factors influencing the growth rate in a stable environment. These can be classified roughly into two groups, (a) factors dependent on or strongly influenced by previous management, i.e. leaf area remaining after cutting and level of reserve substances, and (b) inherent factors largely unaffected by previous management, i.e. photosynthetic capacity and the way in which the products of photosynthesis are distributed in the plant.

The conditions of the experiments approached the optimum for the growth of ryegrass in the available light intensity and a temperature of 17°C. was adopted in most of the experiments. Plants were grown on Hoagland's solution in which the nitrate

content had been reduced to half. The solutions were changed three times a week.

The influence of the level of reserves of soluble carbohydrates on the growth rate was studied in a series of experiments in which different levels of reserves were obtained by placing plants in the dark and at high temperatures and/or high nitrogen levels for comparatively short periods of time (never exceeding three days). The results indicate that reserve level had little or no effect on the rate of increase of dry matter once active regrowth had been established. It seemed in fact that growth proceeded in relation to weight (whether this weight was present in the form of remaining green material or as reserve substances) and that ultimate yield was thus greater from plants with high reserve levels, although it seemed likely that above a certain level no further influence was to be expected.

Some preliminary observations indicate that cutting height is unlikely to affect rate of increase of dry matter production as such under the conditions of these experiments.

Rate of photosynthesis, whether of an individual plant or of a sward, is dependent firstly on the basic photosynthetic capacity per unit leaf weight or surface, and secondly on the efficiency with which the light is intercepted and distributed over the photosynthetic surface, this being largely determined by the angle at which the leaves are presented to the light.

A method has been developed in which the light intercepted by a crop surface can be estimated directly. Small bunches of tillers were grown in holes in a mirror surface and the light intercepted at any particular stage was calculated from measurements of the reflection coefficients of the mirror surface, a closed crop surface and the actual light reflected from the combined crop/mirror surface. It was shown in this way that a more prostrate type of plant can be up to 10% more efficient per unit leaf weight in intercepting light in the earlier stages of regrowth.

In another type of experiment normally prostrate plants were grown in small wire frames to produce an artificially erect habit of growth; top growth after three weeks was reduced by a third.

The basic rate of photosynthesis per unit leaf has been measured in the photosynthesis apparatus which has recently been developed at the Institute. For this purpose the leaves were placed in a flat position in a frame of nylon threads, and exposed to a series of different light intensities. While the possibility of varietal differences in rate of photosynthesis measured in this way cannot

be ruled out, it seems likely that the age of the material could have been a still more important factor and that rates tend to be lower in young regrowth than in the older material.

It has also been shown, using this same apparatus, that at high light intensities (approximately equal to those found at midday in summer) a prostrate type of plant was less efficient than a more erect plant. It is thought that this occurs because effective light intensity is lower with a steeper leaf angle, and photosynthetic efficiency consequently higher.

Experiments have also been conducted in which the growth rate of three different clones have been compared at three different nitrogen levels and also at three different temperatures, with a view to clarifying the way in which these factors influence the growth rate. Results from the first of these experiments suggest that nitrogen supply affects growth rate through its influence on the distribution of the products of photosynthesis between leaves, stubble and roots, and not through any effect on rate of photosynthesis itself at the levels in question. It is hoped to extend the calculations to give information on the sensitivity of the different selections to these factors.

Root studies (A.T.)

Root weight under swards of the same age in successive years. At a number of N.A.A.S. Experimental Husbandry Farms, an experiment has been established to investigate the place of leys in an arable rotation. In this experiment plots of five types of ley are ploughed each year, the age of the leys being the same each year. Through the kindness of the N.A.A.S. it has been possible for six years to determine the root weight of these leys on the Rosemaund E.H.F. at the time of ploughing and so to study the influence of past seasons on root growth and decay without interference from effects due to increasing age of the leys.

Over the whole period 3-yr. old lucerne leys and grass/clover leys of the same age, whether grazed or cut for conservation, had almost the same root weight, 1-yr. clover leys yielded considerably less, and 5-yr. old grass/clover leys somewhat more. The root weight would, therefore, seem to be little influenced by the botanical composition or management of the sward but to increase with the age of the ley. This is in agreement with results previously obtained.

Growth in nutrient solutions of low concentration. A preliminary experiment showed that when grass plants were grown in dilute compared with concentrated nutrient solution the growth of the whole plant was reduced, the shoots to a much greater extent than the roots. Individual plants, however, varied greatly in their reactions.

Two conflicting influences were considered to be acting within the plants growing in dilute solution. The greater the root relative to shoot growth the more the plant would be able to overcome the shortage of minerals. Work with P^{32} has shown that the larger the root system a plant has, the greater is the quantity of phosphorus the roots are able to absorb and translocate to the shoot. At the same time the greater the relative growth of the roots, the smaller the proportion of carbohydrates that would be available for the production of new photosynthetic tissue, and therefore the smaller would be the growth made by the plant as a whole. The ability of a plant to produce a large root system in a dilute solution, may, therefore, be associated with a large or small growth rate of the plant as a whole, depending upon which of the two influences was dominant.

An experiment based on the growth of clones of *Lolium perenne* in nutrient solutions of high and low concentrations was carried out to investigate the relative importance of these two influences. Comparing growth in the low as opposed to the high concentration of solution, the greater the root relative to shoot growth the smaller was the growth of the plant as a whole. This indicated that the lack of carbohydrates for the formation of photosynthetic tissue was the dominant influence. The ability of the larger root system to take up additional minerals modified the effect of lack of photosynthetic tissue and resulted in an increase of growth between 25% and 33%. Investigations are now being undertaken to try to increase this percentage. This possibility is suggested because branched roots absorb more P^{32} than unbranched. The final aim of these experiments is to produce plants with the most efficient type of root system for growing in soils of poor fertility.

Morphological characters and recovery from defoliation in Lolium perenne. The dependence of shoot regrowth upon the size of several parts of the plant has been studied in a number of contrasting environments. An experiment previously reported *Rep. (Welsh Pl. Breed. Sta.* 1960, 61-63) showed that under glasshouse conditions the volume of shoot regrowth one week after defoliation

was positively correlated with the size of the plant before defoliation, and negatively with the amount of shoot left when all the plants were cut to a uniform height of 2 cm. The latter result, which suggests that plants with thin, short bases produce more regrowth than thick ones, has been confirmed in a further experiment in similar conditions. When the plants were defoliated at a greater height, or if the plants were placed in darkness after defoliation, the amount of regrowth was positively correlated with the amount of shoot left. The two measurements were thus positively correlated under extreme conditions, one in which the amount of regrowth depended almost entirely on the photosynthetic activities of the shoot base, and the other in which regrowth was wholly at the expense of food reserves, of which the shoot base is a rich source.

In nearly every environment the regrowth in the week after cutting varied with the amount of shoot present before cutting, i.e. the factors controlling size of shoot during uninterrupted growth were largely operative after cutting. The only exceptions were when the plants were placed in darkness after cutting and when the plants were grown in either very dilute or very concentrated nutrient solutions.

Under most conditions the volume of roots had either no effect on volume of regrowth or else the greater the volume of roots the less the amount of regrowth, suggesting that the amount of carbohydrate used in respiration by the roots was greater than the amount stored in them. The only environment in which a big root system had an advantageous effect on shoot regrowth was when the plants were grown in a concentrated nutrient solution. Under such conditions very little root growth was made relative to that of the shoot prior to defoliation. The period of recovery from defoliation is characterized by a large amount of shoot relative to root growth and the small root systems produced in concentrated solution may not have been able to cope with the demand for water by the shoot system at this time. This would result in the amount of regrowth being positively related to the quantity of roots possessed by a plant.

SEED MULTIPLICATION

Gwilym Evans

PRODUCTION AND DISTRIBUTION OF FOUNDATION SEED (H.M.R.)

During the year under review, 82 acres of herbage varieties were sown and 48½ acres harvested for the production of Foundation Seed. Larger acreages of S.22 Italian ryegrass and S.24 perennial ryegrass were sown this year, due to an increased demand from the N.I.A.B., Cambridge, for Foundation Seed.

Sufficient Foundation Seed was supplied during 1960/61 to the N.I.A.B., for growing 742 acres of Stock Seed, which is a reduction on previous years, and is indicative of the adequate build-up of Stock Seed reserves of cocksfoot and clover varieties. Included in this year's distribution were three new varieties, S.321 perennial ryegrass, (p. 177), S.341 cocksfoot (p. 178) and S.352 timothy (p. 179). Certified seed should become available in 1965 or 1966, depending on the rate of multiplication. In addition to supplying seed to the N.I.A.B., 58 cwt. of S.22 Italian ryegrass were allocated for further multiplication in Northern Ireland under the auspices of their Ministry of Agriculture.

Seed merchants and seed organizations received a total of 101 tons (136 lots) of nine oat varieties bred at the Station for growing-on under recognized cereal inspection schemes. Included in this tonnage was the new eelworm-resistant winter oat Pennant (S.227). An acreage of the new white-grained spring oat Maelor (S.236) (p. 179) was multiplied during the year for initial distribution in 1962.

RESULTS OF EXPERIMENTS

The effect of drill width on the seed yield of grass varieties (H.M.R.)

In a previous investigation (*Rep. Welsh Pl. Breed. Sta.* 1950-56, p.148) it was found that the effect of drill width on the seed yield varied with the species.

In 1959 a trial was established using S.26 cocksfoot at 6″, 12″, 18″ and 24″ spacings at various fertility levels in order further to study the response to drill widths.

Results to date show a progressive reduction in number of seed heads per unit area with increased drill spacing, but inflorescence production was enhanced by increasing the level of nitrogen. Over two harvest years the 18″ spacing gave the best yield of seed in S.26, which compares favourably with results previously obtained from S.37 in the 15″ spacing. The data also show much bigger responses to spring application of nitrogen than to similar amounts applied in the autumn.

Gapping drills (G.E.)

Making gaps of 12″ at 6″ intervals in widely spaced drills of an old stand of a leafy variety of cocksfoot in the autumn reduced the yield of the next year's seed crop, but increased it in the year after. Gaps of 6″ wide at 6″ intervals tended to increase the yield in both years. These treatments were made in conjunction with P.K.N. application in autumn and N. in spring but without such applications marked reductions in yield followed gapping. The evidence suggests that if wide gaps are made in old stands this should be done immediately after harvest coupled with generous manuring.

Root pruning, and effect on seed production (G.E.)

Clones of S.26 cocksfoot, S.24 perennial ryegrass, S.53 meadow fescue and S.48 timothy grown in pots were root-pruned at different times from August to April, leaving only 1″ of root length. October or April pruning delayed head emergence, and the number of inflorescences were reduced progressively with delay in pruning, except in the early perennial ryegrass S.24. Pruning in April failed to reduce the number of heads in S.24 as the inflorescence primordia were already well advanced at pruning time.

The effect of root pruning in April

	Per cent inflorescences relative to control
Perennial ryegrass	106
Cocksfoot	83
Meadow fescue	60
Timothy	57

A few differentiated primordia showed in cocksfoot at the time of April pruning but none in meadow fescue and timothy.

Mean seed (yields gm./pot)

		Month of pruning			
Variety	*Control*	*August*	*October*	*February*	*April*
S.24	6.28	4.49	4.82	2.88	4.60
S.26	13.47	12.70	11.09	11.19	11.95
S.53	8.02	5.41	3.35	4.38	4.87
S.48	4.59	4.36	3.40	4.43	3.21

The two contrasting species in this context were cocksfoot and meadow fescue, the effect of pruning on seed yield being much more marked in the latter. Although the April pruning had not reduced the number of heads in S.24 perennial ryegrass the yield of seed was depressed, indicating that plant nutrition had been affected by the treatment.

Seed yield response of species and variety to fertility (G.E.)

Data from the 1961 harvest confirmed previous results (*Rep. Welsh Pl. Breed. Sta.* 1960, p. 66) that some grasses sown in pots and boxes at different densities suffer much more than others in terms of seed yield under restricted conditions, especially at low levels of nitrogen. Furthermore, leafy or late heading varieties within a species appear to suffer more than stemmy types or early heading varieties. Tall fescue and meadow fescue remained completely vegetative for two harvest years at high density and low nitrogen, while early heading perennial ryegrass under these conditions produced heads and set good seed. Under these impoverished conditions timothy produced more seed in the first year than cocksfoot. The early varieties of cocksfoot and meadow fescue (low density) gave more seed than late heading leafy varieties.

If these findings are confirmed in the field they suggest a *modus operandi* of considerable significance to the seed grower. It is desirable to determine whether land of better quality is more important for seed production of the higher tillering leafy varieties than the lower tillering types, and whether early perennial ryegrass and timothy are less exacting in their demands on natural soil fertility than the fescues and cocksfoot.

Effect of the time of application of ammonium nitrate in the spring on fertile tiller production in herbage grasses (J.L., J.L.S.)

In pot experiments (J.L.S.), using clonally-related single plants derived from S.48 timothy, a standard application of ammonium nitrate equivalent to 4 cwt./acre was applied fortnightly to successive treatment groups. The principal effects can be seen in the following table:

Date of application	*Mean No. heads/plant*	*Mean head length/plant (cm.)*
28 February	70.8	421.8
14 March	69.2	458.4
28 March	69.6	479.7
14 April	77.8	536.8
28 April	77.8	625.8
L.S.D. (P = 0.05)	12.9	75.8
(P = 0.01)	18.1	106.4

There was no significant effect upon the number of heads produced per plant, but later dressings increased the total head length when measured on a per-plant basis. Marked changes were also noted in the distribution of the total head length amongst arbitrarily chosen length categories. Plants which had received early nitrogen showed a wide range in size of head, but with later dressings this spread decreased to the point where 80% of the heads produced could be grouped within a narrow range. These pot studies suggest that for maximum response in terms of seed yield the application of nitrogen in spring should be delayed at least until mid-April. With late dressings, the additional benefit of more even ripening might also be obtained. The unadvisability of evaluating fertilizer treatments solely in terms of the number of heads produced is clearly demonstrated.

In pot experiments (J.L.) using clonally-propagated plants of S.143 cocksfoot, S.53 meadow fescue and S.51 timothy, ammonium nitrate at the rate of 4 cwt./acre was given in single (one application) dressings fortnightly. There was a significant response and the data confirm a previous experiment (*Rep. Welsh Pl. Breed. Sta.* 1960, 67-69).

The pattern of the curve for head production was similar in each variety, with the peak production occurring when the fertilizer was given during the period 21 April to 5 May, followed by a decline with later applications. Meadow fescue and cocksfoot did not respond to dressings given on 2 June, but timothy gave an 85% increase at this date, compared with control.

Date of application	*Mean number of heads/plant*			*Percentage of long heads*		
	*S.*143	*S.*53	*S.*51	*S.*143 >7 *cm.*	*S.*53 >14 *cm.*	*S.*51 >10 *cm.*
Control	9.6	38.8	24.1	65.3	24.6	40.3
10 March	18.4	54.7	39.1	49.6	41.8	34.5
24 ,,	24.3	61.5	44.0	53.8	45.1	49.8
7 April	24.2	61.2	41.8	47.9	53.9	37.3
21 ,,	31.2	69.2	49.7	45.4	52.1	51.9
5 May	33.2	70.3	49.5	63.1	52.3	64.0
19 ,,	18.3	54.9	43.3	68.9	56.9	56.5
2 June	10.9	46.1	43.0	70.3	72.3	40.9

L.S.D. (P=0.05) 9.03
(P=0.01) 11.96

When related to head production the figures for head length grouping make it clear that delaying the application of nitrogen increases total head length. These results agree closely with Dr. Stoddart's data on S.48 indicating that heavier crops of uniform ripening can be produced by delayed nitrogen application. Plants which had nitrogen came into head earlier than the controls, the maximum difference being:

	Days
S.143 cocksfoot	6.8
S.53 meadow fescue	4.3
S.51 timothy	1.9

The optimum time of application does not coincide with any definite developmental stage examined and was 5, 4 and 2 weeks prior to heading respectively in S.53, S.51 and S.143.

Spring temperatures significantly affect the response to nitrogen, soil thermometer readings in March were low for growth, and in these circumstances the plants in pots in the open could better utilize fertilizer applied later.

The influence of daylength and temperature on seed head production (J.L.)

Clonal material of S.53 meadow fescue grown in 7″ pots was introduced to a warm glasshouse under an extended day length of 16 hours' daylight at fortnightly intervals for periods of 4 or 6 weeks from mid-January to the beginning of April 1961.

It was possible to induce earlier heading by early treatment under long days, the earliest emergence occurring in late March after treatment for 6 weeks beginning in January. In every instance where treatment was given early in the year, the range of heading was considerably extended to almost double that of the control. At the same time head numbers were reduced and the total spikelet production was well below the control. Introducing the plants to long days and warm temperature late in the spring favoured a shorter range in heading dates than took place in the control and these plants approximated most closely to the controls in head numbers, and mean head lengths.

Extended day-length	*Number of*		*Range in emergence (weeks)*
	Heads	*Spikelets*	
For 4 *weeks commencing*			
10/1	15.6	322.6	10
24/1	21.0	462.8	11
7/2	8.0	220.2	11
21/2	7.4	180.0	10
7/3	11.0	308.4	10
21/3	11.2	327.4	4
4/4	17.2	513.6	4
For 6 *weeks commencing*			
10/1	10.4	251.4	13
24/1	7.8	215.8	13
7/2	4.2	127.8	10
21/2	7.4	208.0	4
7/3	9.4	262.6	4
21/3	13.0	371.0	5
4/4	18.8	496.2	3
Control	21.4	595.6	6

Mean head length decreased with successive dates of emergence for the control and in plants subjected to treatment late in the season, but head lengths of tillers induced to come into head early were similar even though the date of emergence varied by as much as four weeks.

The best seed production treatments were those which allowed for prolonged periods under short day and low temperature with delayed introduction under long day and warm conditions.

Seed ripeness (G.E., H.M.R., J.L.S.)

Three aspects of this important topic have been studied during the year. Data on seed losses encountered under field conditions provide a useful background to the studies on the physical nature of ripeness and the biochemical changes underlying the process of ripening.

Some loss of grass seeds is expected during normal harvesting operations but the extent to which it occurs can vary greatly from crop to crop. Preliminary studies by the staff of the N.I.A.E. at Silsoe in 1960 with field crops of S.22 Italian ryegrass, S.143 cocksfoot and a timothy variety showed losses respectively of 36%, 26% and 10% (private communication). Further data (H.M.R.) were collected at the Welsh Plant Breeding Station in 1961 from a crop of S.215 meadow fescue which was cut with a binder, stooked and threshed from the field. The yield of clean seed was 375 lb./acre, compared with a mean of 594 lb./acre obtained from 32 sample plots each $\frac{1}{2}$ sq. yd. harvested on the same day as the main crop, and dried under cover. This represents a loss of 37% or £22 per acre, at the current growers' price. It was observed that very little seed was lost at the cutting stage but that substantial shedding occurred in the stook, and also whilst being lifted on to the trailers. There are definite indications that seed losses can be reduced by cutting the crop with the binder at a slightly earlier stage of maturity (*Rep. Welsh Pl. Breed. Sta.* 1959, p. 53). This can also be recommended for grass crops cut with a mower and eventually picked up from the swath. It should be borne in mind, however, that for direct combining the seed should be sufficiently hardened to avoid mechanical injury at threshing, and also ripened to a safe moisture level to prevent heating in the bag, but combine ripeness involves the hazard of shedding.

The relation of seed ripeness to flowering and the physical nature of the endosperm has been further studied (G.E.). The

1961 results confirm previous data and show that differences occur among genera and species of grasses in the time taken between peak anthesis and the stage for maximum seed yields in sets of marked heads of similar age and size. Only 22 days were taken by S.215 and S.53 meadow fescue varieties, S.143 cocksfoot and smooth-stalked meadow grass. On the other hand, an early and a very late timothy respectively took 34 to 38 days. Italian ryegrass seed developed very rapidly taking only 18 days to maximum yield, whereas perennial ryegrass S.24 took 30 days.

Cocksfoot varieties again showed a plateau of at least 8 days at near maximum yield; the Italian ryegrass showed more latitude for harvesting without risk of seed shedding than perennial ryegrass.

In most of the varieties studied maximum yield is reached before the 'cheesy' stage of the caryopsis passes into the 'mealy' stage. Some of the later heading timothy varieties, however, appear to be exceptional, as the endosperm tends to harden before loss of seed occurs through shedding.

Recent studies (J.L.S.) have been concerned with the biochemical changes underlying the process of ripening in early and late varieties of timothy. As a first approach, determinations of total 80% ethanol soluble carbohydrate and total reducing sugar plus sucrose content were made on seed from serial harvests taken at various points during crop ripening both in S.48 and S.51 timothy. In each instance the fluctuations in the sugar fractions during development were essentially the same but the time occupied by the full cycle was less in the earlier flowering variety. The initial phase of ripening consisting of a rapid increase in seed size was characterized by a linear increase in carbohydrate content with time, whilst the second phase, during which gradual solidification of the endosperm took place, was accompanied by a gradual fall in the soluble carbohydrate content of the caryopsis. At the completion of this maturation phase a low but constant soluble carbohydrate level was reached, which showed no further change until after harvesting had taken place. The basic levels were found to be the same in both varieties, i.e. approximately 5% (fresh weight basis) for total soluble carbohydrates and approximately 1% for reducing sugars. A correlation was noted between the point at which this steady carbohydrate level was achieved and the attainment of maximum germination potential in duplicate seed samples. This would appear, therefore, to be a true biochemical criterion of ripeness and it is interesting to note in this connection that at this stage

the seed coat was still green and the endosperm was in the late dough stage. The view that many herbage grass varieties can be harvested at an earlier stage than that which is commonly accepted, is supported by the foregoing results.

The effect of storage conditions on the viability of timothy seeds (H.M.R.)

The artificial drying of timothy seed to 5% moisture was found in a previous investigation to have an unfavourable effect on germination. It has been suggested that the stock used for the investigation contained a high proportion of 'skinned' seed which might be more sensitive to artificial desiccation than normal seed (*Proc. int. Seed Test. Ass.* 24, 184-213, 1959).

Further studies on artificial drying of timothy seed initiated in 1959 show that unskinned seed can withstand extreme desiccation by artificial means. These data show that seed dried to 7.2%, 4.8%, and 2.7% moisture levels maintained high germination over a period of two years in sealed glass tubes and polythene bags under laboratory and seed warehouse conditions. Undried seed, containing 15.4% moisture and stored in sealed glass tubes showed a gradual reduction in germination from 94% to 0% within 18 months. In the presence of a desiccant (silica gel), however, the undried seed gave germination figures at the end of the two-year period which compared very favourably with those of dried seed.

For such a short period of storage the polythene envelopes proved to be as good as the glass tubes for keeping dried seeds and superior than tubes for storing undried seed.

PLANT PATHOLOGY

A. J. H. Carr

The three-fold aims of the research programme are to assess the importance of fungal and virus diseases of herbage crops, to study the epidemiology and host/parasite relationships of these diseases, and to collaborate with the breeding sections in assessing the potential resistance of existing varieties and in the production of new resistant lines.

Disease assessment

Survey work on the effect of phyllody virus on clover seed crops throughout Britain has again been undertaken in 1961 in close collaboration with the National Agricultural Advisory Service. Data obtained by N.A.A.S. seed crop inspectors for 308 white clover crops have been collated and analysed by the Welsh Plant Breeding Station. In addition, a randomly selected sample of 88 of these stands has been more intensively surveyed by N.A.A.S. Advisory Plant Pathologists and the data analysed by Mr. E. C. Large of the Ministry of Agriculture, Fisheries and Food, Plant Pathology Laboratory, Harpenden.

As in previous years (*Rep. Welsh Pl. Breed. Sta.* 1959, 62-63; 1960, p.74) the inspectors' data have shown the virus to be present in 4% of white clover seed crops, with a greater prevalence in older stands than those in their first harvest year. There was a higher incidence recorded in the large-leaved varieties than in the wild white types, and a lower incidence in crops with a large proportion of grass than in relatively pure clover swards. Phyllody remained at a much lower level in red clover, being found in only 7% of the 263 crops examined. In general, the Advisory Plant Pathologists' counts of affected and symptomless flower heads have produced very similar results, indicating that the purely empirical methods of estimation used by the inspectors were reasonably satisfactory in assessing the amount of phyllody present. Their figures were, however, usually higher than those obtained by the inspectors, both in the number of crops infected and in the intensity within stands, particularly when based on observations made about a month later. The inference is that the disease reaches

its peak of expression after the time at which crops are inspected for certification. Even in first year crops, infection levels of the order of 15% flower heads with symptoms were not uncommon.

This joint investigation has shown clearly the value of survey work in assessing the economic importance of a disease over a wide area of sampling, and has also provided useful information concerning the lines along which future research should be directed in the search for effective control measures. The results demonstrate the loss of potential seed yield due to phyllody virus, and also that in order to control the leaf-hopper vectors a greater knowledge is required of their habits, population peaks and relationships with their hosts.

Recently, a start has been made with the assessment of the effect on productivity of endemic grass diseases. *Mastigiosporium rubricosum*, the fungus causing leaf fleck of cocksfoot, has been chosen as a suitable representative of this type of disease for preliminary work. Standard area diagrams were prepared representing 0, 1, 3, 9 and 25% leaf area occupied by lesions and used to ascribe scores to each of four leaves in succession from the apex of 20 tillers taken at random from drills of several varieties at two centres, and in two harvest years. Few varieties were represented at all centres and as they were not replicated at random no statistical treatment could be applied to the results. The table shows a wide variation in mean leaf area occupied by lesions between

Mean percentage leaf area occupied by lesions of Mastigiosporium rubricosum

Cocksfoot variety	*First year*		*Second year*	
	Frongoch	*Cae'r Ardd*	*Frongoch*	*Cae'r Ardd*
Vilmorin	—	1.08	—	—
S. 341	4.22	2.44	9.33	1.95
American	2.41	0.66	—	0.76
Danish	—	0.93	4.26	1.61
S.37	2.22	0.81	—	0.91
Asta	—	0.61	—	—
U.K. Early	—	—	4.63	0.69
Roskilde II	1.44	—	5.35	0.85
Roskilde Late	—	—	—	0.88
Heidenny	—	—	5.18	0.93
New Zealand	1.44	—	—	—
Akaroa	1.98	—	—	—
S.26	1.68	0.54	3.93	0.41
Barenza	1.02	—	5.22	1.95
Hercules	—	—	2.68	—
Penn Late	—	0.44	—	0.68
Portuguese diploid	1.17	—	—	0.31
S.143	1.58	0.88	4.10	0.53

varieties, centres and harvest years, ranging from under 1% to over 9%. There was evidence of correlation of intensity of infection with earliness of heading, the earlier varieties such as S.341 cocksfoot being more adversely affected than later types such as S.143. The area occupied by lesions also increased progressively with leaf age. Mean figures for the four successive leaves for all varieties combined were 0.38%, 1.20%, 2.47% and 3.95%.

In order to determine the effect of these different levels of leaf fleck infection on the nutritive value of the plant, leaf material classified as described earlier was supplied to the Chemistry Section for analysis of total soluble carbohydrate content. All the material was S.341 cocksfoot, one sample from second year drills at Frongoch and the other from broadcast plots. Both samples were taken from the aftermath in which tillers were vegetative, so that the relative ages of the leaves could not be determined and the possible effect of leaf age on carbohydrate content could not be evaluated precisely. The examination of leaves in the various classes, however, did not reveal any strong selection for leaf age with increasing infection level. It was concluded, therefore, that the very striking decrease in total soluble carbohydrate shown in the table is in the main correlated with the percentage leaf area occupied by lesions. A reduction to approximately 50% of the control value at the relatively low level of infection represented by 9% leaf area affected is highly significant in terms of loss of nutritive value; it suggests that the respiratory effect of the pathogen extends well beyond the actual area occupied by the lesion.

Effect of cocksfoot leaf fleck (Mastigiosporium rubricosum) *on total soluble carbohydrate expressed as a percentage of dry matter content*

	Percentage leaf area occupied by lesions				
	0	1	3	9	25
Sample 1	7.3	6.0	5.0	4.0	—
Sample 2	10.3	10.3	7.5	5.0	5.0

The implications of this preliminary investigation are that endemic diseases of the leaf-spot type which are rarely lethal may

have a more profound effect on their host than has previously been appreciated, particularly on chemical yield. Results similar to those given for *Mastigiosporium* might be expected from a whole range of grass pathogens, and further investigations are in progress to determine their effect on the various components of yield.

Effect of chemical treatment on clover phyllody virus

References in the literature to the effect of chemicals on virus diseases of plants include reports by North, Wallace, Ryan and Mueller (*Virology* 8, 131-134,1959), on the amelioration of virus symptoms in *Camellia* by the use of chelated iron, and by Legg and Ormerod (*Rep. E. Malling Res. Sta.* 1957, 129-132), who have discovered that hops infected with nettle head virus have a higher nickel content than healthy stocks. Following a report that workers at the Grassland Research Station, Kitale, Kenya (Poultney, personal communication) had noted some amelioration of clover phyllody virus symptoms with zinc application, a water culture experiment was set up in collaboration with Dr. J. L. Stoddart (Seed Multiplication) to investigate this relationship. Full details will be published elsewhere, but a summary of the main results is given here.

Infected and healthy plants from a single clone of white clover were grown in 4 replicates in a standard aerated culture solution in Doulton pots at levels of trace, 1, 2.5, 5, 10 and 20 p.p.m., Zn as zinc sulphate. The solutions were changed weekly and data were recorded 13 weeks later when flowering ensued. On a percentage basis within each treatment, the proportion of symptomless flowers produced by infected plants increased with higher concentrations of zinc from approximately 1% at the trace level to about 85% at the 20 p.p.m. level. Many of these flowers produced viable seed when crossed with a standard clone of healthy white clover used as male. Marked toxicity symptoms were noted with the highest zinc concentration. The green and dry weight data showed that healthy plants significantly outyielded the phyllody-infected plants over all treatments. A decline in yield was evident in healthy material from 5 p.p.m. upward and in infected material from 2.5 p.p.m. upward. The effect of zinc on flowering was to reduce the number of blooms by half even at a concentration of 1 p.p.m., with a further slight decline at the higher levels. When stolons from infected plants producing symptomless flowers were taken from

each treatment and planted in normal soil, after a period of time all reverted and produced flowers with typical phyllody symptoms.

It is evident from this experiment that the symptoms of phyllody virus are ameliorated by the application of zinc, but in the absence of a technique for the quantitative assay of viruses of the Yellows group in plant tissues it is not possible to determine whether the effect of the metal is to reduce the virus concentration, or to prevent the expression of symptoms by restoring some biochemical process in the host disturbed by the virus. The relationship between zinc metabolism and the abnormal growth-hormone content of flower buds on infected plants reported earlier (*Rep. Welsh Pl. Breed. Sta.* 1960, p. 74; *Proc. Eighth int. Grassl. Congr.*, 1960, 200-204) has not yet been elucidated.

Breeding for disease resistance

Work has continued in collaboration with the breeding sections on selection and breeding for resistance to the more serious pathogens of herbage, including clover stem eelworm (*Ditylenchus dipsaci*), clover rot (*Sclerotinia trifoliorum*), the jassid vectors of phyllody virus and *Verticillium* wilt of lucerne. Mr. P. L. Catherall has commenced a programme of breeding for resistance to the grass rusts, cocksfoot streak virus, and to cereal yellow dwarf virus.

CHEMISTRY

G. ap Griffith

Normal-acid fibre (G. ap G., D.I.H.J.)

The normal-acid fibre method for the assessment of roughage as originally proposed (*Agric. Progr.* 30, 118-128, 1955) after a joint investigation by the Rowett Research Institute, the Grassland Research Institute, and this Station, has been shown to have considerable advantages as a routine method over the classical crude fibre method. The values which it gave, however, were little if any better correlated with digestibility than were those given by the conventional method and this may have discouraged its general acceptance.

It was decided, therefore, at this Station to re-examine the method to ascertain if any alteration in its original form could improve the correlation with digestibility. The main findings of this re-examination may be summarized as follows:

(1) Omitting the preliminary interaction with ethanol-benzene gave a higher yield of fibre but the correlation with digestibility was not as high as with extracted samples.

(2) The strength of sulphuric acid used had a marked effect on the yield of fibre up to strength of 1N but further increases up to 2N had little effect.

(3) Provided the boiling is fairly brisk small variations in rate are not important. Very slow boiling, however, led to an increased yield of fibre and poor agreement between replicates.

(4) The acid/sample ratio could be varied within wide limits. For example, varying the weight of sample from 1 to 0.5 gm. and the acid volume from 100 to 300 ml. had little effect. This may be of some importance, as frequently the quantity of material available for analysis is small.

(5) Using hydrochloric acid in place of sulphuric acid gave consistently lower figures for fibre but failed to give a consistent improvement in the correlation with digestibility.

(6) Increasing the time of digestion with sulphuric acid did have a marked effect. The original proposal was for digestion for one hour and it was stated that small divergencies from this time had little effect.

Though it was confirmed that small changes in boiling time were unimportant a substantial increase in boiling time did affect the result, as the following table shows.

Sample	*Boiling time with N H_2SO_4 (mins.)*		
	60	120	180
Perennial ryegrass	34.0	32.5	31.6
White clover	31.9	28.5	28.1
Farm hay	42.2	40.2	39.7
Oat straw	55.3	54.4	53.9

Jarrige (1961) *Proc. Eighth int. Grassl. Congr.* 1960, 628-635, showed that digestion for 3 hrs. with acid also tends to a better separation between cellulosic and non-cellulosic constituents and suggested that this might result in a better correlation with digestibility. The 3-hr. modification was therefore applied to a selection of samples of known digestibility made available by colleagues in the Grassland Research Institute, Hurley. The effect on the correlation with dry matter digestibility is shown in the following table for S.37 cocksfoot and S.24 perennial ryegrass.

	No. of samples	*Digested for* 1 *hr.*		3 *hrs.*	
		r	*b*	*r*	*b*
S.37	32	–0.91***	–1.869 ± 0.152	–0.94***	–1.582 ± 0.110
S.24	23	–0.80***	–1.714 ± 0.283	–0.93***	–1.652 ± 0.140

*** P = 0.001

All correlations are highly significant but boiling for three hours gives higher *r* values and a lower standard error of the *b* value.

There is an indication that variation between species may be expected as it was found in the present series that at a given digestibility Italian ryegrass showed a consistently lower fibre than

perennial ryegrass. This may mean a separate regression equation for each species, but this is no disadvantage in the examination of breeding material where comparisons are required for screening purposes within one species.

Digestion for 3 hrs. does not increase the work involved but it does make the method a little less attractive for routine purposes. Its other advantages, however, would seem to be substantial.

Nitrate nitrogen content of herbage (G. ap G., D.I.H.J.)

The field experiment on nitrate accumulation (*Rep. Welsh Pl. Breed. Sta.* 1960, p. 77) was continued by Mr. R. J. K. Walters (Grassland Agronomy). The 1961 data confirmed in general the results of the first harvest year, the highest nitrate levels were again reached in the autumn though the mid-season depression was less marked. The levels of nitrate generally were higher in the second harvest year in all varieties, at all sampling dates, and with all fertilizers (nitrate of soda, sulphate of ammonia and urea). S.143 cocksfoot again showed the highest nitrate but the difference between it and the other species was narrowed. Nitrate of soda again induced a much higher nitrate content than did either sulphate of ammonia or urea.

Water soluble carbohydrates (WSC) were determined on the samples from this experiment, and the results demonstrated a close inverse relationship between nitrate content and WSC content. The nitrate content was high at the beginning and the end of the growing season. Closely following this pattern, but in reverse, the WSC was lower at the beginning and end of the growing season and reached a peak in mid-season when the nitrate was lowest. If nitrate nitrogen is toxic, and if the toxicity is reduced in the presence of a sufficient supply of carbohydrate (Sapiro *et al.* 1949, *Onderstepoort J. Vet. Sci.* 22, 357-372) then the importance of the finding that a high nitrate is accompanied by a low WSC is obvious.

Reflecting the inverse relation between WSC and nitrate is also the fact that species differences in nitrate content are also accompanied by similar differences in reverse in WSC. In 1959, for example, S.23 perennial ryegrass was consistently lower in nitrate content in each of the seven monthly cuts than S.143 cocksfoot, whilst the WSC of the former was consistently higher.

With the co-operation of N.A.A.S. colleagues, the geographical range of our observations on nitrate accumulation was further extended. Samples of herbage from four farms in the south-west of England were made available from a series of experiments where nitrogen had been applied at 4 and 8 cwt./acre sulphate of ammonia. None of the four sites showed any accumulation of nitrate at the 4 cwt. level, two showed none at the 8 cwt. level and of these only one had over 0.2% nitrate N. The experiments were a 3^3 design with three levels each of N.P. and K. There was no discernible effect of P. and K. on nitrate content.

Water soluble carbohydrates (G. ap G., D.I.H.J.)

The effect of drying upon the soluble carbohydrate content was investigated. Briefly it was found that:

1. Losses of up to 50% of the total sugars occurred as a result of drying in a laboratory oven at 100°C. overnight without forced ventilation.
2. Drying in the Birmingham and Blackburn Unitherm oven (forced draught) for periods of 2 to 4 hours gave lower apparent losses.
3. Unitherm-dried samples which were then re-dried in a laboratory oven overnight at 100°C. showed markedly lower values for total sugars.

It was concluded that for critical work fresh or freeze-dried material should be used, but for handling the large number of samples from field experiments Unitherm drying may be permissible if carried out carefully and the samples are not re-dried in a laboratory oven prior to analysis. Other work on soluble carbohydrates is discussed in an article on p. 157.

Crude protein (G. ap G., D.I.H.J.)

The usual large number of total nitrogen determinations were made for both agronomists and breeders.

It has been the practice at this Station to do these determinations on the oven dry samples, but it has been suspected that on a routine scale where samples are taken from the oven in batches

this apparent refinement results in the introduction of an error due to variation in the time of cooling before weighing. It was decided therefore to carry out the determinations on the air-dry sample and to correct for moisture, and it was found that individual moisture determinations on each sample were unnecessary and that a composite moisture determination on each batch gave an acceptable correction.

CYTOLOGY

During the past season the work of the section has been continued by Mr. Carroll and his colleagues.

The work has been concerned mainly with carrying out cytological surveys on an extensive series of plant collections from abroad, and with the examination of plants which are of immediate importance to the breeder.

Collections of *Avena* and *Hordeum* spp. (p. 137).

The following species were examined and their chromosome numbers determined in order to verify their identity :

Species	Chromosome No. $2n=$
Avena hirtula	14
A. longiglumis	14
A. strigosa	14
A. barbata	28
A. byzantina	42
A. sativa	42
A. sterilis	42
Hordeum glaucum	14
H. hystrix	14
H. marinum	14
H. leporinum	28
H. murinum	28

Collections of *Festuca arundinacea* from N. Africa (F.A.O.)

The first of these collections from localities in Algeria, Morocco and Tunisia was sent originally from F.A.O. Rome, to the Grassland Research Institute, Hurley. A few plants were aneuploid but most had the normal 2n = 42 chromosome constitution. They were functionally diploid with mean chiasma frequencies/cell ranging from 26.8 to 38.2 in different individuals. Multivalent pairing, mostly quadrivalent, was observed in three plants, reaching

a maximum association of six in one of them (plus a heteromorphic bivalent). A collection from the High Atlas mountains at an elevation of 5,000 ft. (F.A.O. No. 3437 = G.R.I. No. Bs 361) was particularly interesting, in that the plants had a somatic chromosome number of 70 (Plate lg). They showed a predominantly diploid meiosis very comparable with that in the 2n = 42 plants, though multivalents were more frequently encountered; quadrivalents could be found in most plants and some associations of 7 or 8 were seen. There was much plant to plant variation in seed fertility as shown in the following table from data obtained by Mr. Elfed Lewis.

Plant No.	Chromosome No. (2n=)	Percentage seed set (open-pollination)
1	70	57.9
2	70	81.2
3	70/72	11.7
4	70	56.2
5	70	72.9
6	70	38.3
7	70	91.8
8	71	75.2
9	70	63.6
10	70	48.8
11	70	55.1
12	70	33.2
13	70	82.6
14	70	76.9
15	70	85.2
16	70	76.9
17	70	52.9
18	69	No inflorescences produced
19	70	51.0
20	70	67.0
21	70	40.6
22	68	65.2
23	70	51.9
24	—	35.0
25	70	70.0
26	70	57.5
27	—	67.5
28	70	37.5
29	70	46.1
30	70	59.6

It is not known how these 70 chromosome types originated, but it can be tentatively suggested that an unreduced gamete from a diploid *Lolium* or *Festuca* species may have initially produced a 35 chromosome hybrid with the normal form of tall fescue. It is interesting to note that diploid plants (as yet unidentified) were included in 22 further collections of tall fescue from widely different habitats in Tunisia. These plants had the normal complement of 42 chromosomes (Plate 1h).

Collections of *Dactylis* from the Elburz Mountain region, Iran (Imperial College Exploration Board, 1960)

Two localities were represented, a dry limestone habitat at 5,000′, and a wetter site near the limit of oak woodland at 6,500′. Counts were made from representative plants of three samples from the first locality, and of 49 samples from the second. All plants were diploid, $2n = 14$, although a distinct type of morphology was found at each locality.

Chromosome-doubled breeding material

The examination of colchicined material of *Dactylis* in collaboration with Dr. Borrill (Grass Breeding) has continued. Fixations were made for meiotic study from certain genotypes of *D. lusitanica*, undoubled and doubled, and from the undoubled and doubled hybrid with *D. aschersoniana* which is to form the basis of an eventual forage variety. The analysis of this material was unfortunately hampered by extreme chromosomal stickiness. It was possible however to compare two undoubled hybrids with a *lusitanica* parent. The mean chiasma frequencies were:

	Per cell	*Range*
D. lusitanica	11.1	9-14
D. lusitanica × *D. aschersoniana*		
First hybrid	9.4	7-12
Second hybrid	11.0	8-14

It can be seen that individual hybrids may show pairing comparable with the parent type. Nevertheless, an examination of the doubled (tetraploid) form of the second hybrid revealed a chiasma frequency of 23.6, approximately double that in the diploid state. This large relative increase suggests that pairing was actually depressed at the diploid level, and that tetraploidy improved it by allowing a degree of autosyndesis.

Work on the chromosome analysis of induced polyploids involving species of *Lolium* and *Festuca* has continued in collaboration with Mr. Elfed Lewis (Grass Breeding).

Avena: Stabilization of aneuploid lines

The aim of this investigation was indicated in *Rep. Welsh Pl. Breed. Sta.* 1960, p. 80. Counts at root-tip mitosis on progeny seedlings from parents of known chromosome number have been made in order to ascertain the distribution of chromosome numbers. This was considered necessary because partial asynapsis and chromosome elimination, together with other abnormalities, have been observed at meiosis in these plants. Whenever a sufficient quantity of progeny plants was counted it was observed that the diploid numbers were distributed about a mode which did not always correspond with the parental number, for example:

Parents	*Chromosome No.* $2n=$	*Progeny chromosome Nos.*			
SCL 1/3(1)	45	1×44	8×45	6×46	
SCL 3(3)	45	3×42	7×43	3×44	
SCL 4/2(4)	46	1×43	1×44	13×46	1×47
SCL 4/1(1)	46	1×42	4×45	1×46	

Some progenies show a loss of chromosomes compared with their parents whereas others do not. Progress towards a stable form will depend largely on whether selection is capable of improving the regularity of chromosome assortment at meiosis. The selection procedure must, therefore, take into account not only the chromosome number of the selected plant, but also the behaviour of the progeny as a whole.

Hybrids between plants at different polyploid levels (*Anthoxanthum* and *Dactylis*)

Chromosome counting has been carried out on progenies from the crosses of diploid and tetraploid *Anthoxanthum* by the triploid. Strong selection for the success of haploid gametes is apparent in the backcrosses to the diploids, but the selection for diploid gamete action in the tetraploid backcross would appear to be less stringent. When the triploid acted as female parent many more aneuploids were obtained. Altogether the crosses involving the diploid were more successful than those involving the tetraploid. This is in contrast to the situation in *Dactylis* where crosses of triploid by tetra-

ploid produce more numerous and vigorous progeny. Crosses using 3x *Dactylis* as a pollen parent have been attempted this season. A few viable seeds were obtained and only a small number of seedlings raised. These have so far proved to have the same chromosome number as the female parent, but further observation will be needed to determine whether or not they are selfs.

Cytological effects of intensive selection in *Lolium*

Cytological data on Dr. Cooper's selection lines for time of flowering in ryegrass are discussed more fully on p. 115. Additional studies are being made on the cytological consequences of different degrees of inbreeding.

CYTOLOGICAL UNBALANCE RESULTING FROM INTENSIVE SELECTION IN *LOLIUM*

J. P. Cooper and P. T. Thomas

Selection for the extreme expression of a single character often leads to unfavourable correlated responses in other traits, and fertility appears to be particularly susceptible to such unbalance (Mather and Harrison 1949, Lerner and Dempster 1951). A similar situation has recently been found in perennial ryegrass, where six generations of selection for early and late ear emergence in Irish and Kent ryegrass has resulted in a marked decline in both male and female fertility (Cooper 1961).

Fertility is the end result of many co-ordinated physiological processes, ranging from floral differentiation through gamete formation and fertilization to the production of viable seed. The present studies show that it is possible to distinguish between the responses of these different physiological processes to the unbalancing effects of selection.

Material from the sixth generation selection lines for early and late flowering, together with the original populations of Irish and Kent ryegrass, were examined cytologically. The first obvious difference between the selection lines lay in the timing of meiosis relative to ear emergence. In both original populations, meiosis almost coincides with ear emergence. In the early selection lines, however, meiosis does not take place until well after ear emergence, whereas in the late lines it may occur while the ear is still within the flag-leaf sheath. Such differences in the timing of meiosis relative to floral differentiation are known to affect the physiology of meiosis, as in the male-sterile *Lathyrus* (Upcott 1937).

The types of cytological irregularity found in the selection lines are in fact mainly those concerned with the timing of cell division, nuclear development and chromosome pairing. They include premeiotic disturbances, in which failure of cell-wall formation at premeiotic mitosis has resulted in polynucleate pollen mother cells; these nuclei usually arrange themselves on a common spindle at metaphase I (Plate 1a). In addition, binucleate pollen mother cells occur, often showing different stages of nuclear development within the same cell, and occasionally individual chromosomes fail to spiralize (Plate 1b). These premeiotic abnormalities were found at a low frequency in both early and late selection lines from Kent ryegrass.

It was clear that meiotic irregularities had also occurred in previous generations of selection, since trisomics (Plate 1c) and interchanges (Plate 1d) were found in the sixth generation lines. There were also supernumerary fragments in a number of the plants.

In spite of the increase in meiotic abnormalities, the mean chiasma frequency has been affected in only two of the lines (Table 1), being slightly reduced in one of the late Kent lines and markedly so in a late Irish, which contains some completely asynaptic plants (Plate 1f) and many with one or more pairs of univalents (Plate 1e). Even so, several of the selection lines contain a few plants with low chiasma frequency, and both the genetic variation *between* individuals and the developmental instability *within* the plant have been increased in most of the lines. Irish ryegrass, which in the past has been exposed to more stringent agronomic selection for uniformity of flowering, appears to be more sensitive to the unbalancing effects of disruptive selection than does Kent ryegrass in which agronomic selection for flowering time has been more flexible.

The table summarizes the male and female fertility and the cytological behaviour of the selection lines and the original populations. Most of the selection lines show an increase in cytological abnormalities compared to the original populations, but except

Table 1. Cytological behaviour and fertility in selection lines of perennial ryegrass

	Chiasma frequency			*Per cent normal meiosis*		*Per cent*	
	Mean	*Variance*		*Mean*	*Range*	*Stainable pollen*	*Seed set*
		Between plants	*Within plants*				
Irish							
Original population	11.6	0.61	1.19	98.1	92—100	93.0	81.7
Selection lines:							
Early → early	11.0	0.83	1.80	80.4	60—100	69.7	43.1
Early → late	11.2	1.47	1.62	83.5	2—100	76.3	53.1
Late → early	11.5	0.79	1.32	81.9	32—100	60.7	37.1
Late → late	7.9	14.70	(2.70)*	57.4	0— 94	49.1	8.2
Kent							
Original population	11.3	0.70	1.39	93.8	52—100	91.1	56.0
Selection lines:							
Early → early	11.8	0.29	1.08	96.7	88—100	76.6	24.1
Early → late	11.4	0.44	1.76	84.4	56—100	12.1	13.3
Late → early	10.5	1.11	1.89	76.0	18— 96	14.9	37.8
Late → late	11.0	0.36	1.75	89.0	80—100	46.0	1.0

* Omitting asynaptic plants

for the Irish late—→late, which contains some asynaptic plants, these abnormalities are not sufficient to account for all the reduction in fertility. This is particularly the case in two of the Kent lines, early—→late and late—→early, which show very low male fertility but comparatively few cytological disturbances. This reduction in male fertility must evidently have occurred after meiosis, as a result of genetic unbalance operating largely on pollen development, a suggestion which is supported by a comparatively high female fertility in these lines.

In spite of the reduction in fertility and increase in cytological irregularities, however, all selection lines contain some plants of high fertility and regular cytological behaviour, and there is no correlation within the lines between date of ear emergence and either fertility or regularity of meiosis. Disturbances in fertility are not therefore inevitably associated with extreme early or late flowering, and it should be possible to select plants of extreme phenotype which remain highly fertile. It is obvious that although cytological disturbances occur in the selection lines, they can only account for a small proportion of the decline in fertility, most of which must therefore be due to post-meiotic failure.

We thus see that the correlated response associated with intensive selection is the result of developmental instability, which can manifest itself in several ways. These include a reduction in chiasma frequency with an increase in both the *within*-plant and *between*-plant variance, an increase in chromosomal abnormalities, both before and during meiosis, and finally non-chromosomal unbalance. Not only has it been possible to distinguish between these different expressions of developmental instability, but we can conclude that the decline in fertility is determined very largely by non-chromosomal unbalance. These results have been obtained with a moderate degree of inbreeding, and may well differ with different mating systems, since inbreeding itself can result in a marked decline in fertility and increase in chromosomal unbalance (Rees, 1955). Further studies will show how far different degrees of inbreeding during selection can influence the extent and nature of this developmental unbalance.

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Explanation of Plate 1

a. Polyploid P.M.C. at metaphase 1.

b. Binucleate P.M.C. showing differences in nuclear development and failure of spiralization of one chromosome in one of the nuclei.

c. Trisomic plant with one trivalent.

d. Interchange heterozygote with association of four chromosomes.

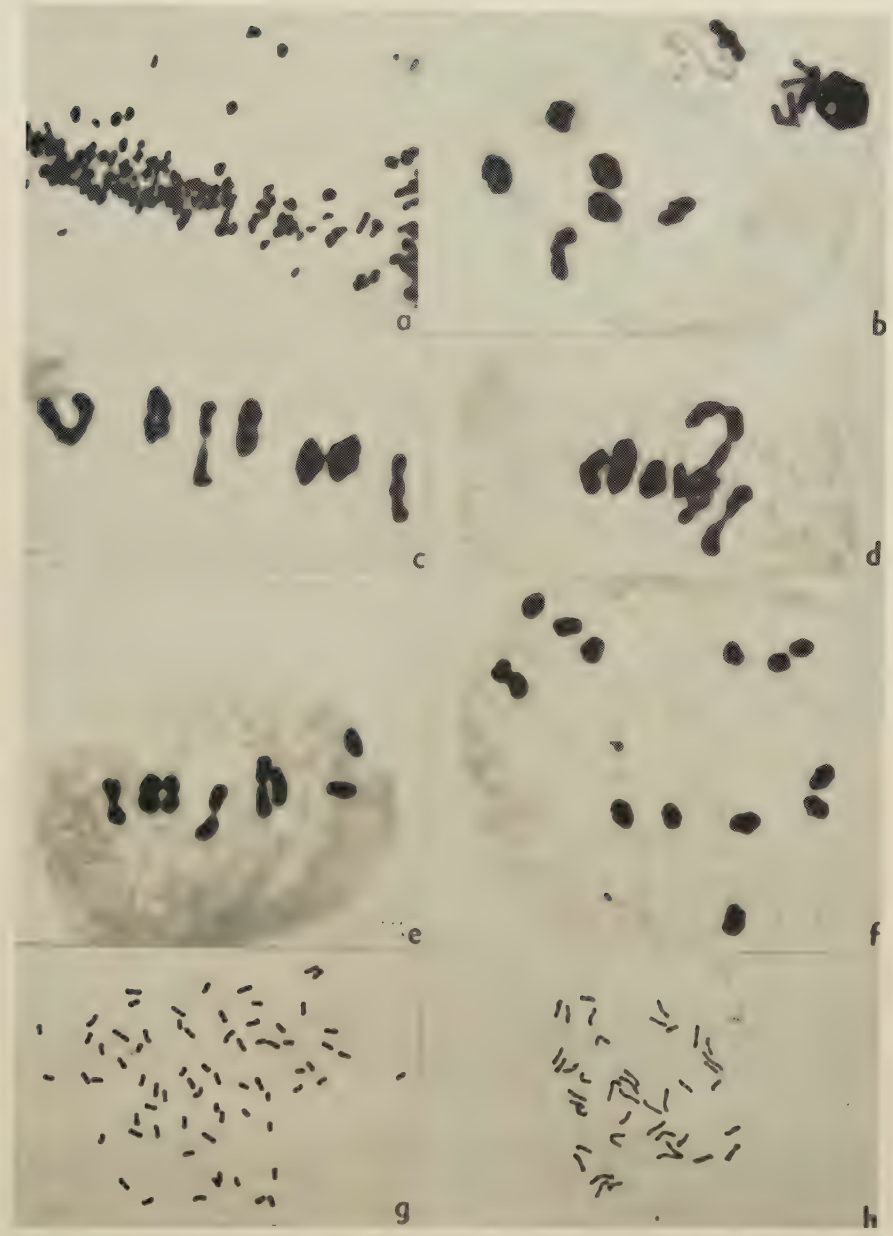
e. Low chiasma frequency and two univalents.

f. Asynaptic plant plus supernumerary fragment.

g. Tall fescue from Morocco (F.A.O. No. 3437 = G.R.I. No. Bs 361) $2n=70$ chromosomes.

h. Tall fescue from Tunisia with normal $2n = 42$ chromosomes.

Plate 1



A. Non-flowering red clover under continuous light.

B. The effects of continuous light plus gibberellin on the same clone of red clover.

AN APPROACH TO THE PROBLEM OF NON-FLOWERING IN HERBAGE SPECIES

J. L. Stoddart

The agronomic potentialities of non-flowering herbage varieties have been discussed by Peterson, Cooper and Vose (1958) and the feasibility of this concept has been demonstrated at this Station by the production of non-flowering genotypes. However, the exploitation of such varieties is at present limited by the lack of flowering response under the practical range of environmental conditions, a fact which, of course, makes seed production an impossible task. Under present conditions a high seed-bearing capacity is an essential prerequisite for the commercial success of a herbage variety, for no matter how good it may be agronomically, the extent of its usage will still be determined by the cost of the seed to the farmer. Therefore, in order to produce an acceptable variety the breeder is now forced to re-select for genotypes with a less extreme physiological behaviour and, consequently, a lower level of useful herbage productivity. On the other hand, the development of a chemical method of floral induction would obviate the necessity for such a compromise and it is with this alternative that the following article is concerned.

The term 'florigen', or flower-generating-hormone, was introduced by Cajlachjan (1936) following experiments in which he and other workers were able to demonstrate that exposure of leaves alone to inductive conditions was sufficient to bring about floral initiation at the shoot apex. Later studies also indicated that flowering could be promoted by the grafting of induced leaves on to a non-induced stock. It therefore became apparent that leaves produce a factor which is translocated to the shoot apex where it brings about a marked change in the pattern of differentiation. A great deal of effort has been subsequently devoted to attempts to isolate a biochemical principle with florigenic properties but to date there has been no indisputable evidence of the existence of such a substance.

Another widely used approach to the problem is that in which chemicals with known growth-regulating properties are applied to plants under threshold photoperiodic conditions. It is then possible to assess their effects upon the flowering response and to make inferences as to the nature of the endogenous processes which they influence. One of the most popular chemicals in this context is

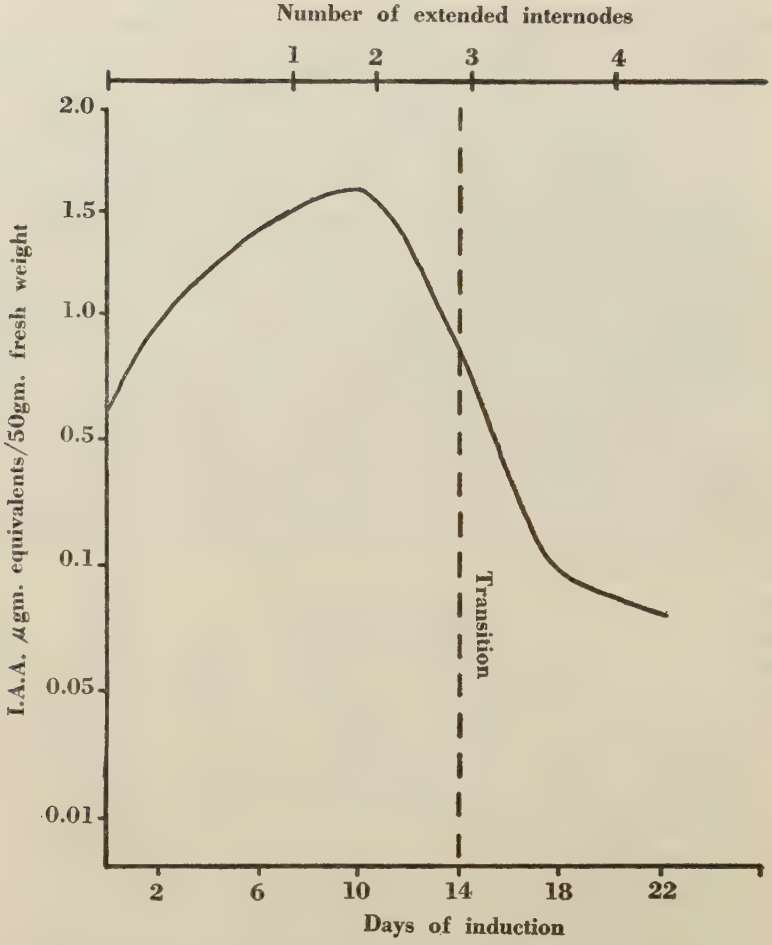


Fig. 1. Changes in I.A.A. content of Aberystwyth S.123 red clover during floral induction. Estimations by *Avena* mesocotyl assay.

3, indoleacetic acid (I.A.A.) which has been shown to initiate flowering under threshold conditions in species as widely divergent as *Hyoscyamus* and the pineapple. Unfortunately these appear to be exceptional cases for in most other plants, including grasses and clovers, I.A.A. is without effect, but it is necessary to point out that such negative results do not rule out the possibility of partial implication of this substance in floral induction or initiation.

Studies of the I.A.A. level in Aberystwyth S.123 late-flowering red clover during the reproductive growth phase have indicated

that there are considerable fluctuations, especially during floral induction. The results of a typical experiment are graphically illustrated in Fig. 1.

In the early stages of floral induction there is a rapid rise in endogenous I.A.A. content but after the commencement of floral initiation there is a gradual decline to a level lower than that initially present. The relationship of the peak I.A.A. content to the point of apical transition is extremely variable and this makes it possible that the implication of this substance in the flowering process is indirect.

Bonner and Liverman (1953) pointed out that treatments which artificially decreased I.A.A. level in Wintex barley tended to increase the number of flowers formed, whilst Liverman and Lang (1956) demonstrated that long-day plants growing under threshold conditions could be induced to elongate stems and initiate flower primordia by the application of I.A.A. Thus the following observations can be made on the apparent role of auxin in flowering:

(a) that a level greater than that normally found in vegetative tissues is necessary for the successful completion of the inductive phase, and

(b) that a comparatively low level is sufficient to allow floral differentiation to proceed at an optimum rate.

These inferred requirements are consonant with the changes in auxin content detailed in Fig. 1 and it can be postulated that photoperiodic induction is reflected in an increased rate of I.A.A. synthesis or a reduction in I.A.A. oxidase activity. The later decline in auxin content could then be attributed to the onset of determinate growth at the shoot apex with a consequent reduction in the rate of auxin diffusion therefrom.

Watanabe and Stutz (1960) have demonstrated that the application of gibberellic acid to the terminal buds of *Lupinus albus* results in a reduction of I.A.A. oxidase activity which, if the same rate of synthesis was maintained, would result in an increased I.A.A. content in the treated plant. The effects of photoperiodic conditions on this oxidase system were investigated by Garay *et al.* (1959) who found that the level of activity in *Lupinus* increased with lengthening photoperiod and they suggested that the effect was based upon the synthesis of an enzyme inhibitor in long-day treated plants. In the light of the previous work it seems likely that this 'inhibitor' is a gibberellin or a product of gibberellin-induced synthesis.

There has been a great deal of discussion on the possible role of gibberellins in flowering and several schemes of action have been suggested. The most recent and probably the most satisfactory so far is that proposed by Brian (1958), who suggested that in response to light 'gibberellin-like' hormones are formed in leaves with a physiologically inactive precursor P as an intermediate product. In darkness the hormone is converted slowly back to P and the process is more rapid if the leaf is exposed to far-red light. Exposure to red light results in the re-formation of the hormone from P. Thus in long-days, increasing concentrations of gibberellin will be produced and short-day levels will be correspondingly lower. High levels of gibberellin will, therefore, induce flowering in long-day plants and low levels will initiate this process in short-day species. Day neutral plants are regarded as being independent of light for gibberellin synthesis. Brian postulates that 'florigen' is formed at a later stage during gibberellin-induced reactions.

The fact that gibberellic acid ($G.A._3$) is ineffective in bringing about floral initiation in grasses and clovers under conditions which do not favour the process would seem to be contradictory to the foregoing hypothesis but as Lang (1956) has pointed out, gibberellins of different plants may not be identical and, therefore, might not be interchangeable. Thus a given gibberellin could be without effect on flowering even where endogenous gibberellin level was the factor limiting the process. To date, nine gibberellins have been extracted from plant material and their activity spectra in various bioassay procedures vary considerably. It is frequently the case that 'gibberellin-like' activity isolated from plant extracts can be attributed to more than one source and this may indicate that several forms of gibberellin are necessary in the growth correlation of a single species. For example, in red clover it is possible to detect two 'gibberellin-like' zones on chromatograms derived from ethanol extracts. One zone has a chromatographic and bioassay behaviour similar to that of authentic $G.A._3$, and the quantitative fluctuations observed in extracts made at various growth stages show a good correlation with the rate of stem extension. On the other hand, the second zone shows a greater chromatographic mobility than $G.A._3$ in a variety of solvents but it is not detectable in the extracts until a time corresponding approximately with the apical transition to the reproductive condition. Determinations of 'gibberellin-like' hormone content in flowering and non-flowering genotypes after a standard exposure to inductive daylength conditions are detailed in Fig. 2.

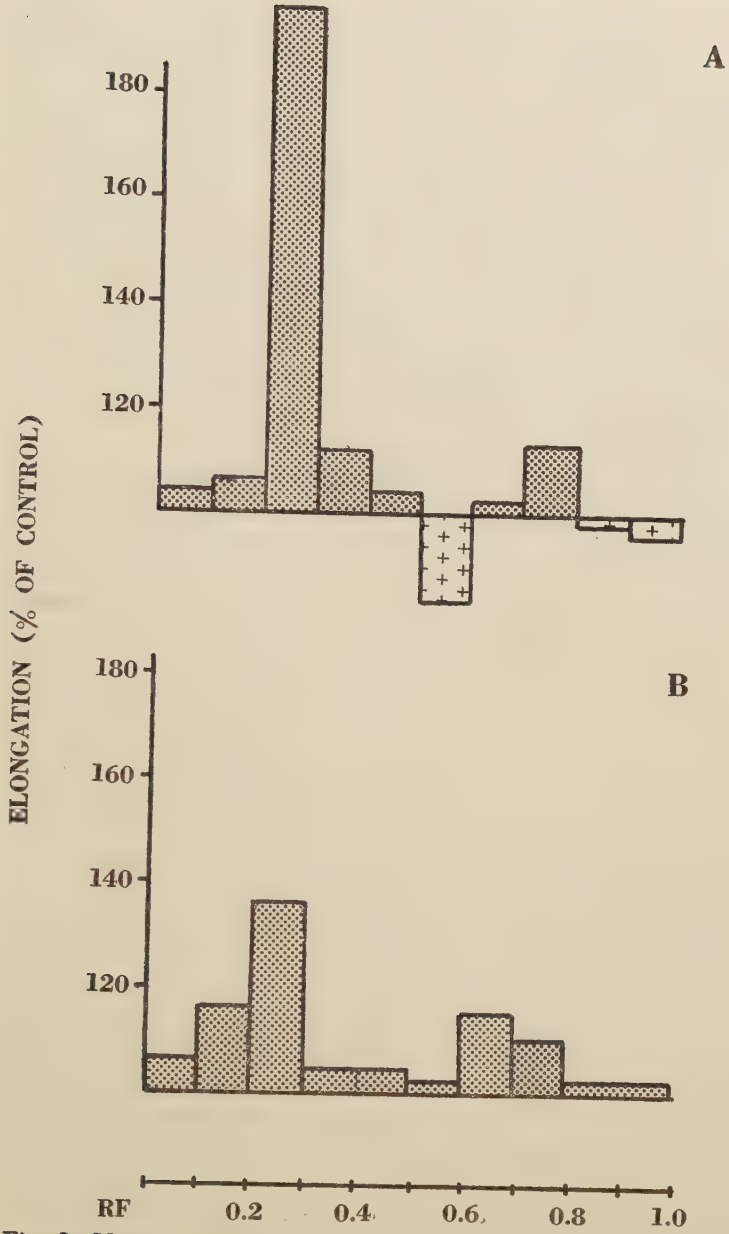


Fig. 2. Meteor pea assays of "gibberellin-like" activity present in red clover extracts after 14 days under inductive daylength conditions.

A. Normal genotype from Aberystwyth S.123
B. Non-flowering genotype from Aberystwyth S.123

It is noticeable that the Rf 0.3–0.4 ($G.A._3$ zone) activity was more pronounced in the normal material which was in a state of active stem extension at the time of sampling. The magnitude of the second 'gibberellin-like' zone is very similar in both instances and this might possibly be related to the fact that both genotypes still had vegetative apices. After floral induction the content of the Rf. 0.6–0.7 'gibberellin' usually increases markedly. The close correspondence in chromatographic behaviour between the Rf 0.3–0.4 'gibberellin' and $G.A._3$ suggests a convenient test of the postulated function, for if this form of endogenous activity is concerned with stem extension it should be possible to initiate this process in the non-flowering genotype by treatment with $G.A._3$ at regular intervals. The result of such an experiment is illustrated in Plate 2 and it can be seen that this treatment does result in stem production which is followed by profuse flowering.

The latter response is somewhat unexpected, for earlier work on normal genotypes of S.123 grown under threshold photoperiodic conditions had shown that applications of $G.A._3$ could not induce flowering but were effective in initiating internode extension. Furthermore, non-flowering genotypes maintain a strictly vegetative shoot apex even under continuous illumination but in the presence of $G.A._3$, which promotes stem extension, the apices become reproductive. It seems likely, therefore, that a two-factor system controls shoot and flower development in this species, the first part controlling stem extension via a '$G.A._3$-like' promotor which is produced as the result of a principally temperature-dependent process. The second part is envisaged as a daylength-mediated reaction, based upon products of the primary system, which results in the elaboration of the 'florigenic' stimulus.

Thus the failure of $G.A._3$ to initiate flowering in normal genotypes under non-inductive conditions would be due to the non-functioning of the secondary daylength-controlled system, whilst the insensitivity of non-flowering genotypes to favourable photoperiods could be explained by a blockage in the primary system which would preclude flowering even if the daylength-mediated reaction was present. One possible form of the system is indicated by Fig. 2, which suggests a conversion of the '$G.A._3$-like' activity to another structural form of gibberellin capable of bringing about enlargement of the shoot apex and stimulation of the lateral meristems.

On turning to the problem of non-flowering in ryegrass further difficulties are encountered, for in this species there is a winter

requirement which must be fulfilled before internode extension or flowering can take place under favourable photoperiodic conditions. In addition it must be noted that floral initiation precedes internode extension and not vice versa as in red clover. These observations tend to suggest that stem extension and floral initiation are controlled by a common system, but a study of non-flowering genotypes (material provided by Dr. J. P. Cooper) has shown that this may not be the case. For instance, when the continuous light/ $G.A._3$ treatment, previously described, is applied to such plants they respond by producing apparently normal stems, but do not form inflorescences, even in genotypes which normally begin initiation but do not complete the process. There are also flowering ryegrasses with atypical behaviour in that they extend stem internodes under inductive daylength conditions but do not initiate floral structures without cold or short-day exposure, (e.g., Ba 6280 and Aberystwyth S.23, Cooper 1961). It therefore seems that the two-factor system advanced for legumes, whilst still applicable to grasses such as timothy where there is no winter requirement, must be modified before it can explain the situation in ryegrass or other species with similar physiological requirements. The bridge can be made by the simple hypothesis that whilst the primary system is present from an early stage in clover and timothy, it is only produced in ryegrass as a result of low-temperature or short-day induction. Thus we have the theoretical possibility of producing non-flowering variants either by selection for increased winter requirement or for increased critical daylength and, therefore, in studying chemical induction in such varieties it is necessary to approach the problem from two different directions.

From the foregoing observations it seems that at least part of the response to low-temperature or short-day is concerned with the inception of endogenous gibberellin synthesis which, under long-day conditions, attains a level sufficient to promote stem extension. The production of a 'florigen' under inductive daylength might start from the same biochemical baseline as the stem-initiating principle, but by virtue of a lower effective concentration, or a more rapid reaction rate, it could reach a level sufficient to bring about floral initiation before the concentration of gibberellin necessary to encourage stem extension had been attained. In interpreting this hypothesis it would be necessary to assume that the level of the 'gibberellin-like' primary product arising from the winter-induced reaction was mediated by daylength according to Brian's scheme and that the necessary level for stem extension was only achieved in day-

lengths approaching the threshold for flowering. It would also be essential to propose that the daylength-mediated reactions responsible for the flowering stimulus were initiated during the cold or short-day treatment. On this basis it is possible to interpret the Ba 6280 or S.23 behaviour as being due to the dependence upon winter induction for the daylength-mediated system but not for the stem extension components.

Gibberellin specificity may again be involved in that the 'florigenic' stimulus might result from a chemical alteration of the 'gibberellin-like' stem extension principle suggested earlier, and this aspect of the problem is being actively studied at present.

Thus far only the effects of growth-regulating chemicals on flowering have been considered, as these are commonly thought to be the rapidly-translocatable stimuli operative in the co-ordination of plant morphogenesis. However, in relation to the flowering response it is equally important to consider both the site of photo-perception and the region of floral differentiation. In the former instance, the recent isolation by Hendricks and Borthwick (1959) of a red/far-red reversible pigment system subsequently named phytochrome, has done much to elucidate the mechanism whereby plants perceive changes in photoperiod. The reaction can be written as:

$$PH_2 + A \underset{\text{7,350 Å max.}}{\overset{\text{6,600 Å max.}}{\rightleftharpoons}} P + AH_2$$

in which PH_2 and P are the reduced and oxidised forms of the pigment with absorption maxima near 6,600 and 7,350 Å respectively whereas A and AH_2 are a hydrogen acceptor and donor. The authors state that the pigment P is an enzyme controlling an 'essential reaction'. Because the pigment reaction is not a true equilibrium an excess of the oxidised form tends to accumulate under daylight illumination. In the case of long-day plants the threshold concentration necessary to initiate and maintain further reactions is only achieved in daylengths in excess of the critical value for the species in question. No evidence is available on the reactions controlled by the phytochrome system but, as Brian (1958) has pointed out, the effects of red light and gibberellin on various physiological processes are largely interchangeable.

The use of monochromatic light in the active spectral wavebands to influence flowering and morphogenesis is an attractive idea but on a field scale it would be fraught with practical difficulties, and in the case of plants with the ryegrass-type of flowering behaviour it would be useful only when no blockage of the winter-

induction system existed. As a tool, therefore, for bringing about floral initiation in non-flowering genotypes it is only likely to be useful when employed in conjunction with other treatments designed to overcome the winter requirement barrier.

Finally, it is necessary to consider the changes induced at the shoot apex by the translocatable stimulus or stimuli originating from the phytochrome shift. The basic manifestation of floral initiation is a change in the rate and siting of cell divisions at the shoot apex, and it has been noted that large changes in the cellular content of ribose nucleic acid (R.N.A.) occur during the transition of the apex to the reproductive condition. This suggests a correlating role for R.N.A. and implies that one of the chemical consequences of the response to inductive photoperiod is a change in the molecular structure of this compound. Recent experiments in which modified bases have been introduced into plant R.N.A. molecules at various stages of development have indicated that the constitution of this substance is of fundamental importance in the control of morphogenesis, a finding which holds promise of leading to reliable and easily applied methods of controlling plant development.

Thus, it is clear that there are many approaches to the problem of non-flowering in herbage species and in the case of red clover it has been shown that the chemical induction of flowering is a feasible proposition, at least in plants with the simpler type of flowering response. With the present widespread emphasis on problems associated with the physiology and biochemistry of flowering and the modern techniques at the disposal of the research worker it would now seem to be only a matter of time before the barriers to flowering control still existing in other species are finally removed.

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SEED PRODUCTION STUDIES WITH S.53 MEADOW FESCUE

Joseph Lewis

An analysis of seed statistics for the year ending 30 June 1961 (*Seed Tr. Rev.* 13, p. 233, 1961) shows that whereas 3,738 cwt. of S.215 meadow fescue were sold for seed mixture purposes only 1,394 cwt. of S.53 were sold. This lack of popularity of S.53 is not in keeping with its agricultural worth and perhaps the price differential between the two varieties has much to do with the situation. Seed growers are entitled to expect this price variation, as it would appear that the yield of S.53 has been consistently lower than that of S.215 over the past 13 years (*Lincolnshire Seed Growers Association Report*, 1960, p. 11). According to this report the maximum yield in 1960 of S.215 was $7\frac{1}{2}$ cwt./acre, and of S.53 only $3\frac{1}{4}$ cwt./acre. And yet yields of $7\frac{1}{2}$ cwt./acre of cleaned seed have been reported for S.53 in seed production trials in Essex (Hayward 1959). It must be possible, therefore, to raise the seed yields of S.53 by better management of seed crops so that the average production approaches more closely to the maximum for this variety.

The concept of a grass sward as a population of tillers in a dynamic state of change (Langer 1956) would be equally applicable to the special purpose seed crop. The aim, however, is to manage a seed crop in such a way that the normal sequence of growth and development is controlled and the crop becomes more akin to a cereal crop which has all tillers fully reproductive at the same time. In order to follow the course of tiller development in S.53, clonal propagants of a single parent plant of the variety were studied on a tiller basis. Tillers were marked at monthly intervals from December onwards as they appeared through the subtending leaf sheath. The influence of tiller age on such factors as seed weight and yield per tiller was then determined and the contribution of tillers of the different age categories to total production assessed (Fig. 1).

The tillers which are on the plant by the end of the year produce a higher yield/tiller with seeds of better quality. Although the early formed tillers are more productive than those originating in spring, their contribution to total yield is not as great as that of the later formed tillers. This is due to the preponderence of spring tillers in the total fertile tiller population of the harvested crop. Spring nitrogen increased the contribution of all tillers to the final seed yield but because of the extra response which it produces in

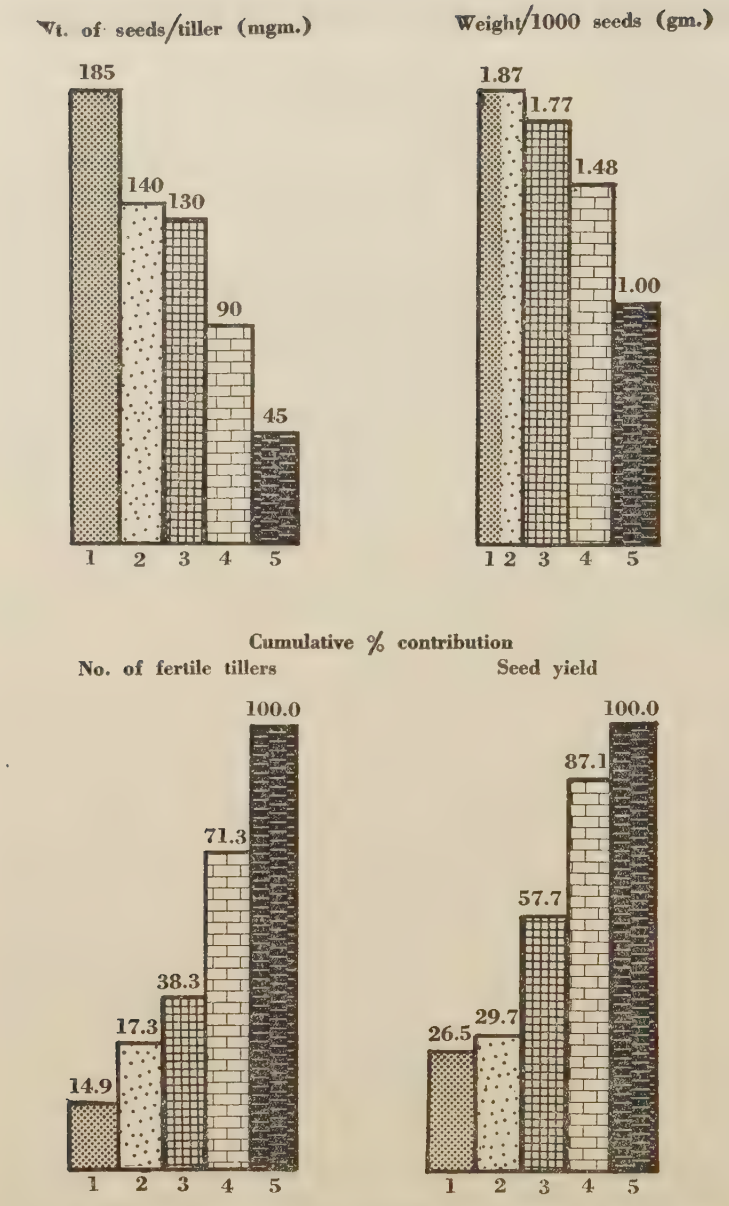

Fig. 1. S.53 meadow fescue showing influence of time of tiller origin.

spring tillering the contribution of the overwintering tillers becomes proportionately less.

The higher yield/tiller of those which originated before the beginning of January raises the question as to whether total yield can be increased by inducing greater tillering by the end of the year, and also whether it is feasible to manage a seed crop with this as its sole aim. To this end the influence of the time of sowing and seed stand establishment was investigated, since it was deemed possible by this means to produce plants of varying size and tiller density by the first autumn. The results in Table 1 indicate that plants with the greatest number of robust tillers in the autumn also gave the most seed.

Table 1. *Fertile tillers and seed yield from plants established from seed sown at monthly intervals*

Month of sowing	*No. of fertile tillers/sq. ft.*		*Seed yield (lb/acre)*	
	1960	1961	1960	1961
March	46	33	372	246
April	47	35	425	249
May	25	36	298	233
June	16	34	228	186
July	15	34	214	191
August	7	36	122	277

The influence of tiller number on seed yield was clearly indicated in 1960 but was not so marked in 1961. The results showed that the benefit from early sowing was maintained for one year only since the differences were non-significant in the second harvest year. The main advantage of early sowing and the development of robust autumn plants would appear to be derived from the more prolific spring tillering which they induce, a fact which emerges from the lower yield of seed per tiller from plants with high fertile tiller densities.

Similar results for one seed harvest have been obtained from a drill crop of S.53 in which April sowings were superior to June sowings and these were significantly better than yields from later bi-monthly sowings.

Meadow fescue plants grown under high competition in impoverished conditions are restricted in their inflorescence production

(Gwilym Evans, p. 93), which suggests another possibility of controlling the fertile tiller population of seed stands. If it is possible to promote the contribution of overwintered tillers by this means it would result in the production of even ripening crops of high seed yielding capacity.

Plant density has been investigated in two experiments in which fertilizer treatments were superimposed. In the first experiment a spacing of 36 sq. in./plant was compared with 54 sq. in. on small plots of clonally-propagated units of four parental plants of S.53. In the first harvest year the S.53 did not tiller sufficiently to compensate for the increase between the narrow and wide spacings, so that although yield of the individual plants was higher from the wider spacing, the yield/acre was significantly greater from the narrower spacings. Yield and fertile tiller numbers were 15% lower on a unit area basis in the 54 sq. in. treatment for the first harvest year but these were non-significant in the second harvest year.

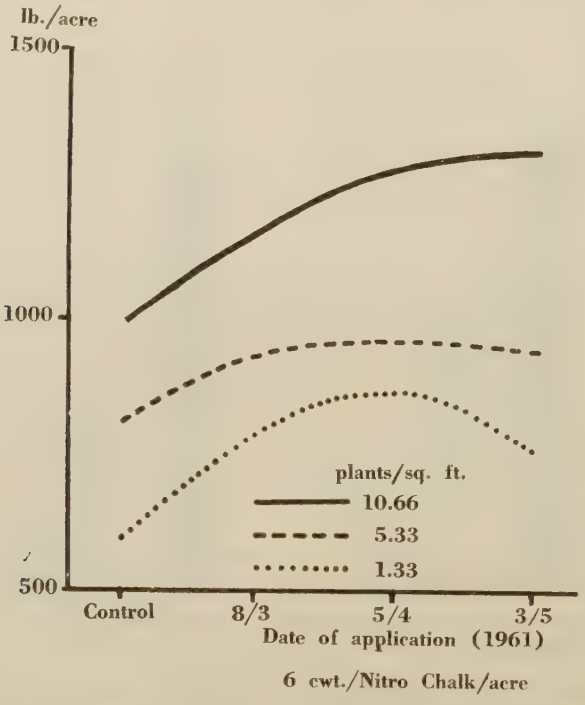

Fig. 2. Yield of Seed (light + heavy)

The above results were confirmed in the second experiment in 1961 in which clonal units of a single parental plant of S.53 were spaced in boxes at varying densities. Yields on a per plant basis were higher from the thin sowings but on a per unit area basis they were higher from the thicker plant populations. The results confirm those of Roberts (1961), showing that S.215 meadow fescue produced more seed from narrow drill spacings of 6″ and 15″ than from drills 24″ and 36″ apart.

In these two experiments the influence of the time at which the plants were given a nitrogenous fertilizer was also examined. The results are shown in Fig. 2.

Plants at the closer spacing, as well as giving the highest return for the applied nitrogen, also gave the best response to the late application, a point which comes out clearly when the yield of seed/100 tillers is considered.

Table 2. Seed/100 tillers (gm.) for three plant densities

		Plants/sq. ft.		
		10.66	5.33	1.33
Control		7.33	7.60	7.53
N. applied	8/3/61	7.50	7.82	7.61
	5/4/61	8.72	7.51	7.65
	3/5/61	10.63	8.34	8.44

In the experiment involving the two densities 36 sq. in. and 54 sq. in. per plant the influence of timing the application of nitrogen followed a parallel trend in the low density plants, giving a heavier seed yield in response to the nitrogen applied early than to that applied late, although both were significantly higher than the control.

Table 3. Yield and fertile tiller response to 6 cwt./acre Nitro-Chalk applied before and after apical differentiation

	Harvest year	*Control*	*Nitro-Chalk applied*	
			Early	*Late*
Seed yield lb./acre	1960	456.7	721.5	633.3
	1961	439.5	802.0	675.5
No. fertile tillers/sq. ft.	1960	68	80	76
	1961	84	92	68

An attempt has been made to promote autumn tillering by giving generous applications of nitrogen in September, but the results show that nitrogen applied in spring is far more effective in increasing yield. Significant returns followed the March application of Nitro-Chalk at 6 cwt./acre in each of two harvests.

Nitro-Chalk 6 *cwt./acre applied in*	*Seed yield (lb./acre)* *Harvest year*	
	First	*Second*
Autumn	581.8	563.0
Spring	924.5	943.2

This tends to confirm that the only value to be expected from giving nitrogen in the autumn would be in promoting tiller development in backward stands, and in this way help towards increased output of spring-formed tillers, which could be further encouraged by extra nitrogen in the year of harvest.

Confirmation of the advantage of applying nitrogen in spring emerged from a pot experiment in which clonal propagants were given varying rates of ammonium nitrate. Table 4 shows that nitrogen applied in autumn promotes fertile tiller production to a much lesser extent than equivalent rates applied in spring.

Table 4. *Fertile tiller production in response to ammonium nitrate applied in autumn and spring*

Ammonium nitrate (cwt./acre)	*Fertile tiller production/plant*	
	Autumn	*Spring*
0	25.4	25.4
2	29.8	48.4
4	39.4	67.8
6	41.8	69.0
8	36.8	84.8

In view of the continued response at all levels of nitrogen it would be worth considering applying higher rates to seed stands of S.53. This is particularly worth further investigation since Hayward (1959) was able to obtain high yields of $7\frac{1}{2}$ cwt./acre after 6 cwt. concentrated complete fertilizer and 6 cwt./acre nitrogenous fertilizer (15% N.). Such amounts should preferably be given in

split dressings as there is a tendency for leaf scorching with high rates of nitrogenous fertilizers. One difficulty of such high rates is the liability of the crop to lodge, although some lodging must be tolerated if maximum yields are to be realized. Too early lodging would tend to depress yield. This point was brought out in a trial in which a drill crop of S.53 artificially lodged by means of steel mesh frames at an early stage of anthesis reduced seed yield to 68% of the control plots, while severe lodging a fortnight later lowered it by only 15%.

Defoliation at different stages in the development of a crop has wide implications for its seed production. Earlier work at this Station has shown that for S.215 meadow fescue defoliation by cutting or grazing can only be practised with safety during the dead period (Roberts, H. M., unpublished data). The defoliation of S.53 in early spring, however, although showing the variety to be less severely affected than S.215, still indicates the need for restraint. A follow-up experiment with S.53 suggests that early spring nitrogen can compensate for the defoliation effects by the increased production of fertile tillers, but there are indications that these are not producers of good heavy seed.

It is worthy of mention that the weight/1000 seeds of S.53 is lower than that of S.215, the mean figures for Foundation and Stock Seed over a 10-year period being 1.744 gm. and 2.121 gm. Seed processors may allow a much lower bushel weight of cleaned seed in the pasture variety if seed crops are kept free of weeds. A considerable quantity of germinable seed of good quality can be lost if cleaning operations are not judiciously executed.

Practical implications

In order to achieve good returns from seed crops of S.53 meadow fescue attention has to be given to several important factors:

1. Seed crops should be established from early sowings, preferably without a cover crop, on account of the difficulty in establishing good stands of this species. The use of pre-emergence weed killers on a stale seed bed would be worth considering for the establishment of weed-free crops.

2. Broadcast stands would give more economical returns than drills, provided the land is clean and in good heart.

3. The careful use of heavy applications of nitrogen is necessary to promote good tiller development in the autumn, but more particularly to increase the number and size of the spring tillers. A dressing in May would be advantageous to a crop which had failed to respond to earlier applications.

4. If defoliation is necessary it should be done during the dead period and the crop compensated for removal of tillers by extra nitrogen.

5. Seed cleaning should be cautiously done so as to save the lighter seed, which is often lost through too severe cleaning.

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PLANT COLLECTION IN PORTUGAL 1961

Roy Hughes, M. Borrill, I. Davies, and J. D. Hayes

In a particular region plants survive by adaptation to a specific environment. An intensified agriculture drastically changes the biotic and edaphic factors. Indigenous material seldom possesses the variation necessary fully to exploit the new environment and the plant breeder must look elsewhere for the attributes required. Thus for out-of-season growth in Britain plant collections can be made in areas where low winter production is not essential for survival. In hill environments tolerance to low base status and fluctuating water regimes, specific reactions to temperature and light intensity, and perhaps marked periodicity in growth pattern, or the lack of it, take on a special importance for the breeder.

Cereal breeders at the Welsh Plant Breeding Station maintain an active interest in fundamental research in the *Avenae*. The aspect of evolution and genome relationships within the species is one consideration, while interspecific hybridization to transfer desirable genes from one species to another has a far-reaching importance in crop improvement programmes. The success of such investigations depends largely on the range of wild species available for study and every opportunity should be taken to obtain the widest range of material from the most promising sources.

The Iberian Peninsula on the fringe of the centre of origin of the primitive oat species is of extreme interest. Species such as *Avena longiglumis* and *A. Hackelii* have been reported in this area but never collected for critical study, and the whole peninsula abounds in *Avena sterilis*, *A. barbata* and *A. strigosa* representing respectively the hexaploid, tetraploid and diploid genomes. Another interesting feature is the widespread distribution of *Hordeum* species.

Portugal offers great interest to the herbage breeder and ecologist as a result of the influences of the Atlantic, the Mediterranean and the Spanish Meseta, which give rise to startling climatic gradations between these extremes. This attraction is enhanced by a formidable altitudinal range in almost all regions, but more particularly in the North. Already grasses of Portuguese origin examined at Aberystwyth have been shown to be valuable, e.g., diploid cocksfoot and tall fescue.

General Description of Portugal

Portugal lies approximately between latitude 37° and 42°N. and longitude 7° and 9°W.; it is about 340 miles long and 70–120 miles wide. The country is dominated by a high central ridge running N.E. to S.W.; the highest range is the S. da Estrela (mainly granite) which rises above 6000 ft.

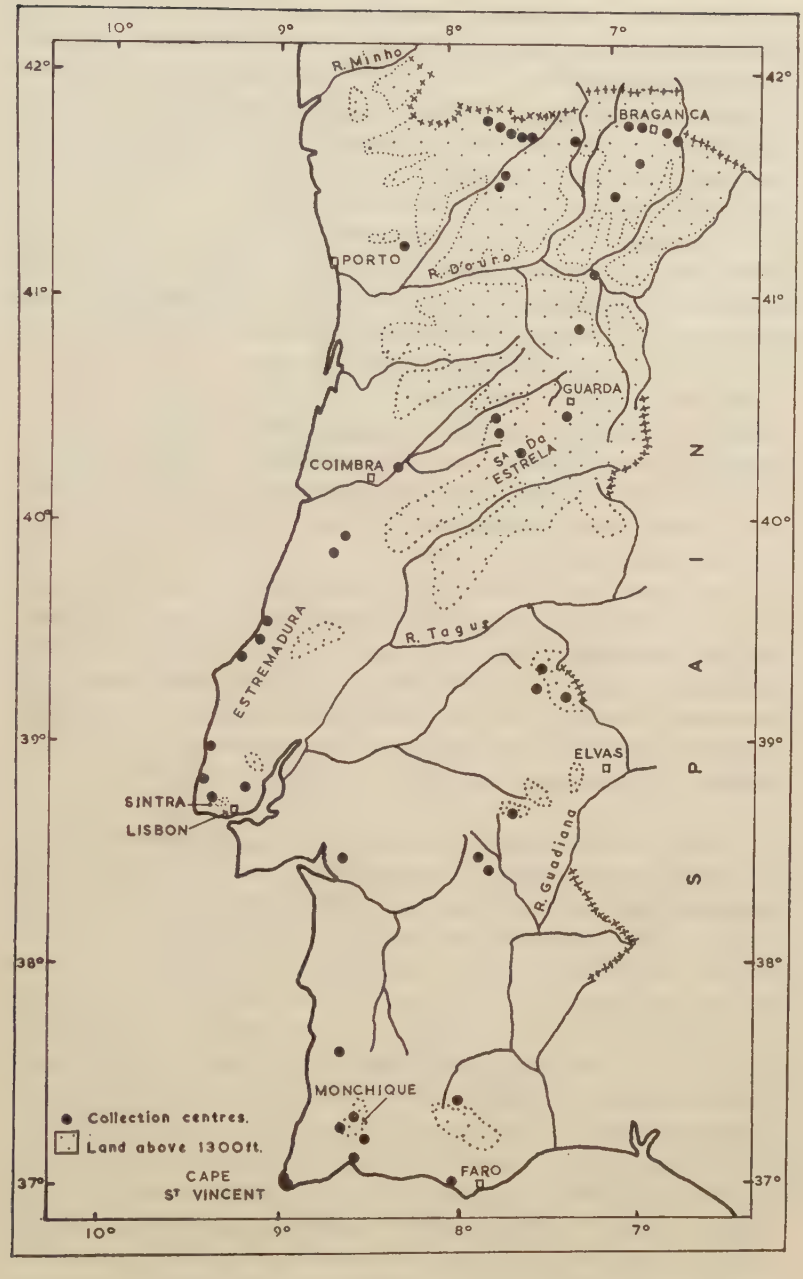
The main soil groups follow a geographical pattern. Over most of the northern plateau occur thin, acid, peaty mountain soils, grey podzolic types and thin stony lithosols, derived in the main from granites and schists. Rocky outcrops are numerous. Most of the remainder of the country south of the river Tagus, is made up of sandy or siallitic shales derived mainly from ancient slates, sandstones and crystalline rocks; these soils are invariably acid and infertile. Dry calcareous soils occur in the Estremadura northwest of Lisbon, and in the Algarve in the extreme south.

North of the Tagus most of the area exceeds an elevation of 2000 ft. The deep sheltered valleys have a mild, dry climate with Mediterranean species locally abundant, in marked contrast to the western heights, which are exposed to the sea winds. Temperature and humidity increase inland rather than from north to south and the whole region is characterized by warm summers, mild winters and a general high rainfall above 35″ per year nearly everywhere and more than 50″ in the higher zones.

In the coastal lands and S. Portugal conditions become rapidly warmer towards the south; the mean January temperature ranges from 49° to 52° F. and frost is practically unknown. Mean annual rainfall also decreases southwards, e.g., Pôrto, 46″; Lisbon, 27″; Faro, 20″. Where the Mediterranean influence is dominant the rainy season is October to December and the summer is hot and very dry. It is not surprising, therefore, that the main cereal growing area is in the south and the pasture areas of greatest interest are in the north, especially the north-east.

Collection areas

Collections were made in south-west France and the central plateau region of Spain *en route* for Portugal and also in the coastal regions of Galicia and the Cantabrian foothills in north Spain on the homeward journey. The main collecting effort, however, was concentrated in Portugal during two intensive weeks in mid-June. The centres fall naturally into two main areas (map).



Collection Centres in Portugal 1961

South of the Tagus and Estremadura. In this area the agriculture is very diverse both regarding the type of crops grown and the intensity of the farming. In the Algarve, the foothills of the Serra de Monchique and in the Estremadura, intensive fruit culture, maize and rice are found involving terracing and irrigation. Cereals, olives and cork oak cover the major part of the landscape, with some heath and rough pasture in the south-west.

The collections were mainly confined to the higher ground and coastal regions, the Serra de S. Mamede and the Serra da Ossa in the east central region near Elvas, the Serra de Monchique in the south-west, the Serra de Sintra west of Lisbon, the southern coastline and that from Lisbon northwards to Nazare.

In the east-central zone altitude did not markedly alleviate the influences of the Iberian climate. Collections were made in wooded or scrub-clad sites and close to streams. The vegetation of the Serra de Monchique was predominantly Mediterranean, but it is likely that the cloudy conditions prevailing near the summit result in ecotypic differentiation.

The routes from Elvas to Faro and from Cape St. Vincent to Lisbon were traversed very rapidly, but we saw few of the more temperate grasses, and it is highly probable that they are virtually absent; for example, only one plant of *Festuca arundinacea* was encountered south of the Tagus. In the Estremadura, especially between Leiria and Coimbra, this species was more frequent, but confined to ditches and the vicinity of irrigated rice fields.

The Serra da Estrela and the north-east. In the Tras-os-Montes particularly, stock-rearing has a place in the farming economy and in marked contrast to the south, relatively intensively managed pastures occur. Nevertheless, arable predominates and cereals, potatoes, olives and vines are cultivated in the lowlands. To the west, the vine becomes more important and there is more intensive arable farming, often in terraces. On the coastal region Italian ryegrass leys are introduced into the rotation. In marked contrast to the South, Atlantic influences extend into the easternmost regions of North Portugal. The route from Coimbra north-east to Manteigas (S. da Estrela) and then north to Bragança traverses a region of great climatic interest since pockets of distinctly Mediterranean influence occur in the valleys of the Douro and its tributaries.

The rock-strewn high mountains of the Serra da Estrela carry only a very thin vegetation. *Nardus*, *Festuca rubra*, *Erica* and *Galium* occur in sheltered pockets and at intermediate altitudes.

At lower elevations flushed meadows with *Festuca rubra* and occasionally *Lolium perenne* occur along with species indicative of Atlantic influences.

North of the Douro *Lolium perenne* is markedly more frequent and is almost invariably in very wet meadows under a pH 4.5 to 5.5. *Festuca arundinacea* is generally in moist habitats but is also found in distinctly dry situations.

Many of the meadows with a high proportion of *Lolium perenne* are low-lying and benefit greatly from silt deposition following intense rainstorms. Two hay crops are often taken, in April and June, and the swards are sometimes grazed in winter. The other common practice is close scything every 4–5 weeks.

The relative abundance of natural meadows, the sharp transitions from Atlantic to Mediterranean climatic influences and variations in altitude all point to the great potential of north-east Portugal as a source of material. This area afforded almost the only opportunity for the collection of perennial herbage legumes. The seed of *Trifolium repens* was, however, mainly unripe and the total collection amounted to 5 seed and 8 vegetative samples.

The distribution of the cereals was variable. For instance, *Avena sterilis*, *A. barbata*, *A. strigosa* and *A. sulcata* as well as *Hordeum marinum* were collected at many locations along the itinerary. *H. leporinum* occurred on the roadside practically everywhere. The single collection of *A. longiglumis* found at Arabia, 'the place of the Moors', near Faro, in the Algarve is of interest, as the last collection of this species in Portugal was recorded in 1937. Attempts to find *A. Hackelii* recorded near Cape St. Vincent at the turn of the century were unsuccessful. Similarly, it was not possible to establish the existence of *Avena clauda* in Portugal at the time of our visit.

Collecting techniques

Cereals. Eight to ten ripe heads of each species were collected at every location. Species identified in the field in the mature condition as *Avena sulcata* Gay on subsequent seedling classification at the Welsh Plant Breeding Station would appear to be actually *Helictotrichon* Besser, similarly most of the *Hordeum* material collected proved to be *H. leporinum* Link.

Herbage. The aim was to sample wild populations of herbage plants on the widest genetic basis and, therefore, seeds were collected

and wherever possible a minimum of ten seed heads were taken from each locality. Most of the herbage species are cross-fertile and these seed heads include the whole range of potential biotypes in the populations. The alternative method of taking tillers from divots is very time-consuming and laborious, the greatest overriding disadvantage being that only few genotypes can be taken from each population. This method was used when ripe seed-heads were not available, as was the case with *Lolium perenne* in northern Portugal.

At each collection site a comprehensive list of the associated species was compiled and a note taken of the soil type and pH, the exact location, altitude etc., and thus a reasonably full characterization of the environment can be made. As far as possible each species was collected over its whole ecological range.

The following list summarizes the plants collected and their geographical distribution.

South Portugal and Estremadura

Species	*Localities*	*Species*	*Localities*
Agrostis setacea	1	*Festuca* spp.	2
Avena barbata	7	*Helictotrichon* spp.	2
A. byzantina	2	*Holcus lanatus*	2
A. longiglumis	1	*Hordeum leporinum* Link	14
A. sativa	1	*H. marinum* Huds.	2
A. sterilis	12	*H. vulgare*	2
A. strigosa	6	*Lolium multiflorum*	1
Dactylis hispanica	3	*L. rigidum*	6
D. lusitanica	1	*Lolium* spp.	3
D. marina	10	*Phalaris minor*	2
Festuca ampla	2	*Poa pratensis*	1
F. arundinacea	2	*Trifolium repens*	2
F. spadicea	2		

Monchique		*Sintra*	
Avena albinervis	1		
Dactylis glomerata	1	*Avena barbata*	1
D. hispanica	2	*Dactylis lusitanica*	2
Festuca ampla	2	*Helictotrichon* spp.	1
Helictotrichon spp.	1		
Vulpia spp.	1		

Serra da Estrela

Species	*Localities*
Anthoxanthum amarum	1
A. aristatum	2
Festuca spadicea	1
Holcus lanatus	1
Lolium perenne	2
Lolium spp.	1

Northern Portugal

Species	*Localities*	*Species*	*Localities*
Anthoxanthum aristatum	3	*Holcus lanatus*	7
Avena barbata	1	*Hordeum hystrix* Roth	1
A. sterilis	2	*H. leporinum* Link	4
A. strigosa	4	*H. marinum* Huds.	1
Cynosurus cristatus	3	*Lolium multiflorum*	4
Dactylis glomerata	1	*L. perenne*	7
D. hispanica	1	*Lolium* spp.	1
Festuca arundinacea	8	*Poa pratensis*	2
F. rubra	6	*Poa trivialis*	2
Festuca spp.	1	*Trifolium repens*	3

Handling the collections

The first operation with the cereals is to verify the identification of some of the species. Root-tip chromosome counts and disease reactions of seedlings are still in progress and will be followed by a critical study of the morphology of mature plants of each species. Those with promising attributes and species of value in interspecific investigations will be retained for further study.

For the herbage plants the initial stage of examination procedure is largely governed by the small amount of viable seed generally available. After positive identification, the collections will be screened and classified according to the potential attributes of the material for current and future breeding programmes at the Station. Those that show particular taxonomic and genetic interest will be more fully investigated.

The first stage will be undertaken in the nursery at the Welsh Plant Breeding Station where each collection will be established as spaced plants in the early summer of 1962. A close spacing will be adopted so that observations will reflect as nearly as possible conditions that prevail in a sward. The preliminary lowland screening will be invaluable in providing information that will allow the reduction of the number of lots that will ultimately be studied in hill environments.

SELECTION FOR NUTRITIVE VALUE

J. P. Cooper

Over the past thirty years, the plant breeder has been successful in developing a valuable series of grass and clover varieties which provide a sequence of leafy and palatable herbage through most of the year, and which are well adapted to both grazing and conservation.

At the same time, the genetic study of these outcrossing herbage species has shown that most locally-adapted varieties contain a wealth of genetic variation for such important morphological and physiological characters as time of flowering, rate of leaf and tiller production, leaf area (Cooper, 1961a) and the uptake and utilization of minerals (Vose 1961). These characters respond rapidly to selection, and high and low lines well outside the range of the original variety can be produced in a few generations (Cooper 1961b).

In view of the importance of the nutritive value of herbage, the question arises whether similar genetic variation exists for such nutritive components as digestibility or protein and carbohydrate content, which could then be utilized in a selection programme to provide the optimum nutrition for the animal.

It has been known since the early work of Fagan and Jones (1924) that leaf has a lower fibre content (and therefore presumably a higher digestibility) than stem, and this led to concentration on leafiness in the breeding work at Aberystwyth. More recently, Minson *et al.* (1961) have shown that ryegrass and cocksfoot herbage swards in the spring remain at a high plateau of digestibility until ear emergence, when the digestibility begins to fall at a regular rate. A late-flowering variety, such as S.23 ryegrass, thus maintains a high initial digestibility for a longer period than does an early-flowering variety like S.24. The exact level of the plateau varies with the species, cocksfoot showing a consistently lower digestibility than ryegrass at all stages of development.

Pilot studies have, therefore, been started in collaboration with the Chemistry Department to discover how much genetic variation for nutritive components exists in herbage varieties, and to assess the possibilities of selection for increased nutritive value. So far, most information is available on water soluble carbohydrate and crude protein content, though attention is now being given to *in vitro* digestibility (Tilley *et al.* 1961).

Protein and soluble carbohydrate

Varietal differences. Varietal differences in protein and soluble carbohydrate content are being studied in a range of climatic races of ryegrass and cocksfoot grown as seedlings throughout the year (p. 16).

The soluble carbohydrate content shows marked seasonal and environmental effects (Jones p. 157). Although all the material

Table 1. *Varietal differences in water soluble carbohydrate and crude protein content*

Varieties	*Per cent water soluble carbohydrate*			*Per cent crude protein*
	20 *March*		30 *May*	30 *May*
	Warm house	*Cool house*	*Cool house*	*Cool house*
Ryegrass				
Melle pasture	8.4	17.2	39.3	7.75
Pajbjerg late	8.9	16.0	38.0	5.55
Russian	6.7	15.9	35.7	8.45
S.23	6.2	14.6	36.5	7.92
Irish	6.2	14.6	35.2	8.17
New Zealand	6.7	13.3	37.2	8.43
Algiers	5.3	16.7	32.1	8.03
Oregon	7.1	17.1	32.6	8.35
Cocksfoot				
Russian	5.3	18.7	33.0	4.82
Danish	8.0	17.9	33.1	7.20
S.341	5.3	10.6	30.3	7.65
Palestine	4.5	12.7	29.0	6.52
Norway	5.3	7.5	27.6	8.60
S.143	4.5	8.9	23.7	8.07
Portugal	5.3	11.2	21.8	7.87
L.S.D. 5%	2.5	4.0	4.6	1.7

was vegetative and cut at the same age, the carbohydrate level increased from spring to early summer, probably as a result of increase in light energy. High temperatures, on the other hand, decreased the carbohydrate, as shown by a comparison of the warm and cool glasshouse samples (Table 1).

Even so, regular species and varietal differences have been found. In the ryegrasses, the continental pasture varieties Melle and Pajbjerg late were consistently high, while the Mediterranean ecotype from Algiers was the lowest. In the cocksfoots, the range of values was much greater, with the continental varieties Russian and Danish highest, and S.143 and the Portuguese diploid much lower. In general, cocksfoot was lower than ryegrass in soluble carbohydrate, although Russian and Danish overlapped the lower end of the ryegrass range.

Varietal differences in protein are also apparent, although the seasonal pattern of variation has not yet been worked out. Pajbjerg late ryegrass and Russian cocksfoot were much lower in protein than the others, but there was no consistent differences between ryegrass and cocksfoot.

These results show that varietal differences in soluble carbohydrate and in protein exist in both ryegrass and cocksfoot, and suggest that screening of a wider range of varieties under more closely controlled conditions should be profitable.

Genotype and family differences. It is also important to know how much genetic variation is carried within a variety, since selection within an already adapted variety, if possible, should prove the easiest way of improving its nutritive value.

Analyses have, therefore, been made of a number of individual genotypes of ryegrass and cocksfoot, and the progenies derived from them by pair-crossing. The ryegrass included Irish and S.23, though only the S.23 plants were used as parents, while the cocksfoots comprised a small number of plants of S.37, S.143, S.341 and Brage. All the analyses were made on vegetative material; the parents were cut either in the spring or in the aftermath, and the progenies were harvested in the seeding year after an April sowing.

The soluble carbohydrate and protein values for individual genotypes and family means are given in Table 2.

Even a single variety, S.23 ryegrass, contained a range of 7.4% to 17.4% soluble carbohydrate and 17.0% to 32.0% protein, and similar variation occurred between the cocksfoot genotypes. These differences were reflected in the ryegrass and cocksfoot families,

Table 2. Genotype and family differences in water soluble carbohydrate and crude protein content (1961).

	Per cent water soluble carbohydrate				*Per cent crude protein*			
	Mean	*Range*	*L.S.D. 5%*	*n*	*Mean*	*Range*	*L.S.D. 5%*	*n*
Genotype differences								
6 April								
S.23 ryegrass	10.9	7.4—17.0	3.6	31	25.5	17.0—32.0	unavailable	28
Irish ryegrass	13.1	9.8—15.9		11	25.1	22.4—27.6		9
20 September								
Cocksfoot †	7.4	4.2—13.6	2.4	30	17.1	13.1—20.9	3.7	36
Family differences								
5 July								
S.23 ryegrass	21.9	15.5—31.6	5.2	14	16.7	12.4—23.2	5.6	14
Cocksfoot †	11.7	5.4—17.7		18	15.2	11.6—19.4		18
6 August								
S.23 ryegrass	31.3	25.5—35.6	5.4	14	8.5	6.2—10.8	2.2	14
Cocksfoot †	16.3	8.3—28.8		18	8.2	6.1—10.6		18

† includes S.37, S.143, S.341 and Brage.

although the absolute values varied with the date of cutting. The July cut showed high protein and a moderate carbohydrate level, while in the August cut the protein level was very low and the soluble carbohydrate correspondingly greater. Cocksfoot again showed consistently lower carbohydrate values than ryegrass, although the higher cocksfoot families just overlapped the ryegrass range. There were no regular differences in protein between the two species.

Heritability. Genetic variation in both protein and carbohydrate content evidently exists between individual genotypes and families of ryegrass and cocksfoot. The efficiency of selection, for these components, however, depends on the extent to which the differences between the parental genotypes are transmitted to their progeny, that is, the heritability.

The heritability estimates calculated from the correlation between the progeny means and mid-parent values are quite encouraging, particularly since the parents and progeny were cut at different dates. In the cocksfoot, the estimates for carbohydrate

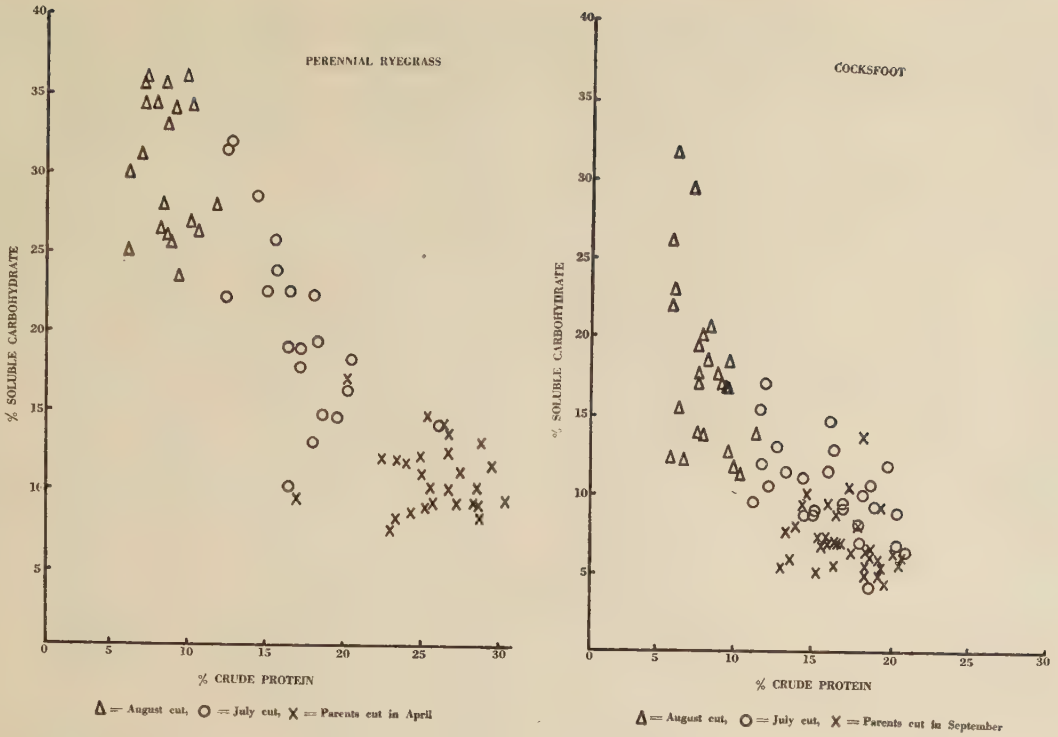


Fig. 1. RELATION BETWEEN % CRUDE PROTEIN AND % SOLUBLE CARBOHYDRATE IN RYEGRASS AND COCKSFOOT PARENTS AND PROGENIES.

Table 3. Heritability of water soluble carbohydrate and crude protein content

	Soluble carbohydrate		*Crude protein*	
5 *July cut*	*r*	*n*	*r*	*n*
S.23 ryegrass	0.62	14	0.75	10
Cocksfoot †	0.78	12	0.53	12
6 *August cut*				
S.23 ryegrass	0.11	14	0.20	10
Cocksfoot †	0.56	12	0.69	12

† includes S.37, S.143, S.341, Brage.

and for protein at both cuts were over 0.5, while in ryegrass, the figures for the July cut were high (over 0.6) but in the August cut neither protein nor carbohydrate showed a significant value. It must be remembered that the parents showed high protein and low carbohydrate levels (Fig. 1) and were more similar to the July cut in this respect.

Even the present small number of families and of sampling dates have thus revealed useful additive genetic variation for these two nutritive components, and rapid response to selection would be expected. A wider programme of screening and selection within existing ryegrass and cocksfoot varieties should provide even greater opportunities for genetic improvement.

Correlated responses. Although selection for either protein or carbohydrate individually should be effective, genetic changes in one of these components might well produce unfavourable correlated responses in the other. It is known from field trials (Jones *et al.* 1961) and from glasshouse studies (Vose p. 25, Alberda 1961) that an increase in nitrogen supply, while increasing the protein content results in a decrease in soluble carbohydrate, and vice versa; changes brought about by selection may show a similar effect.

There is in fact a strong overall negative correlation between protein and soluble carbohydrate content in the present ryegrass and cocksfoot parents and progenies (Fig. 1). This correlation is in part environmental; the parents, grown as spaced plants, have high protein and low carbohydrate levels; the August cuts, taken

on the broadcast families, have very low protein and high carbohydrate, while the July cut is intermediate for both characters. Even so, some genetic correlation exists, as shown by the correlations *within* sampling dates (Table 4), particularly in the July cut, which had the widest spread of both carbohydrate and protein.

Table 4. Correlations between crude protein and water soluble carbohydrate content

	Ryegrass		*Cocksfoot*	
	r	*n*	*r*	*n*
Parents	–0.25	28	–0.35	36
Progenies (July cut)	–0.70	20	–0.57	25
Progenies (August cut)	–0.20	20	–0.48	25

In spite of this negative correlation, however, the range of possible combinations of protein and soluble carbohydrate is quite large and should accommodate most values required by the breeder and agronomist. For instance, herbage of a protein content of 14% could be obtained with a range of 17% to 30% carbohydrate in ryegrass, and 5% to 16% in cocksfoot. The soluble carbohydrate content for the same protein level is always lower in cocksfoot than in ryegrass.

One important limitation in establishing a selection programme at present is not lack of genetic variation but shortage of information on the optimum protein and carbohydrate levels required by the animal.

In vitro digestibility

Although protein and soluble carbohydrate are important nutritive components, probably the most important factor determining the nutritive value of herbage is the extent to which it is digested by the animal, and the digestibility may also influence the amount of herbage the animal will consume.

Estimations of *in vitro* digestibility (Tilley *et al.* 1961) for certain of the above ryegrass and cocksfoot samples have been carried out by the Biochemistry Department, Grassland Research Institute, Hurley (Table 5).

Significant genotype differences occurred between plants of S.23 ryegrass, with a range from 63.3% to 83.5% although most plants had values of over 80%. The cocksfoot genotypes, cut in the autumn, also showed a wide range 52.5%—67.5% with a mean of 60.7%. Family differences were detected in ryegrass and cocksfoot at both cuts, although the variation was not so great as for protein and carbohydrate. The differences were greatest in the August cut, which showed lower overall digestibilities, and would probably be greater still in more mature herbage. Cocksfoot was consistently lower than ryegrass throughout, as found earlier by Raymond *et al.* (1960).

In spite of the significant family differences, particularly in the second cut, the heritability estimates for ryegrass were low and not significant. There was, however, little variation between the actual parents used in the crosses, all were very high (80% to 85% digestibility) and little practical improvement would be expected from selection. In cocksfoot, however, with a lower mean digestibility and a wider range between the actual parents used for crossing, the heritability figures were encouragingly high (0.52 and 0.53) and effective response to selection would be expected.

Table 5. *Genetic variation in* in vitro *digestibility*

	Mean	*Range*	*L.S.D.* 5%	*No. of plants or families*
Genotype differences				
6 April 1961				
S.23 ryegrass	79.2	63.3—83.5	not available	30
20 September 1961				
Cocksfoot †	60.7	52.5—67.5		35
Family differences				
5 July 1961				
S.23 ryegrass	82.4	79.9—85.9	3.2	15
Cocksfoot †	76.3	73.2—79.6		18
6 August 1961				
S.23 ryegrass	76.0	70.0—79.9	3.6	15
Cocksfoot †	65.5	60.3—70.0		18

Heritability	*S.23 ryegrass*	*Cocksfoot* †
July cut	—0.29	+0.52
August cut	+0.17	+0.53

† includes S.37, S.143, S.341, Brage.

The genetic relationship between digestibility and soluble carbohydrate and protein is also important. Although a high soluble carbohydrate content will contribute towards high digestibility, the correlation is far from complete. Comparisons of individual genotypes of S.23 (Table 6) show that two plants cut

Table 6. Relationships between in vitro *digestibility, soluble carbohydrate and protein in genotypes of S.23 perennial ryegrass*

	Per cent		
Plant No.	In vitro *digestibility*	*Soluble carbohydrate*	*Protein*
Ba 7683	82.3	9.1	28.6
Ba 7714	65.8	9.5	17.0
Ba 7712	82.8	17.0	20.2
Ba 7721	82.5	8.3	28.8

on the same date may have the same digestibility yet differ markedly in soluble carbohydrate content, while others may have the same carbohydrate content but differ in digestibility. As Table 6 indicates, this lack of correlation may in part be due to a different amount of protein in the material.

These results suggest that although digestibility is of primary importance, the soluble carbohydrate and the protein content of the digestible part of the herbage may vary considerably, and estimates of all three components are desirable to obtain a coherent picture of nutritive value.

Discussion

The present results indicate that useful genetic variation for protein and carbohydrate content can be found both ***within*** and ***between*** ryegrass and cocksfoot varieties, and response to selection should be immediately effective.

The possibilities of selection for high digestibility vary with the species. In the ryegrass material, although genotype and family differences have been detected, the range of digestibility in young leafy material is not great, and differences *within* the species may become important only in more mature herbage, particularly at or after the time of heading. Cocksfoot, on the other hand, which is usually less digestible than ryegrass, offers more scope for improvement. The encouragingly high heritability estimates suggest that it should be possible to develop cocksfoot varieties which are just as digestible as ryegrass.

The successful development of a selection programme for nutritive characters, however, requires more information on three main points. In the first place, the exact nutritional requirements of the ruminant are far from clear, and although high digestibility is presumably of primary importance, the optimum levels of carbohydrate and protein may be different for meat and milk production. Raymond *et al.* (1960) have suggested that on most herbage swards in Britain, animal production is limited by available energy, i.e. by carbohydrate rather than by protein. A substantial part of the energy requirement of the ruminant is obtained from volatile fatty acids produced in the rumen (Phillipson, 1947). It has been suggested (Balch, 1961, Tilley *et al.* 1961) that a diet high in fibre and low in soluble carbohydrate produces a high proportion of acetic to propionic acid, while low fibre and high carbohydrate give a low acetic to propionic ratio. The proportion of the different volatile fatty acids appears to have a marked effect on milk composition, butter fat content being increased by acetic acid and decreased by propionic acid. An important extension of the present work would be to select lines of the same digestibility but of different carbohydrate and protein levels which could then be used in nutritional trials with different types of livestock.

Secondly, the present results are derived from a few cuts of vegetative material grown in pots or boxes. It is known that both soluble carbohydrate and protein content are greatly influenced by the light and temperature regime, the level of nitrogen, and by the frequency and height of defoliation (Vose, p. 25, Jones, p. 157, Alberda 1961). Both these components and digestibility are strongly affected by flowering and seed production. A knowledge of the seasonal pattern of soluble carbohydrate, protein content, and digestibility throughout the year is therefore essential for any selection programme. This pattern is now under active investigation by Mr. D. G. Miles (Grassland Agronomy) and Dr. D. I. H. Jones (Chemistry) using single-genotype swards, while the influence of nitrogen nutrition on carbohydrate and protein content in a range of ryegrass varieties is being studied by Mr. P. B. Vose (Developmental Genetics) and Dr. E. L. Breese (Grass Breeding).

Finally, there is the problem of combining these different nutritive components with each other and with other agronomic characters in an improved variety. This can be done either by selecting within existing varieties, or by introducing specific characters from other material. Selection for the extreme expression of

any trait may lead to unfavourable correlated responses in other characters. In perennial ryegrass, for instance, selection for rapid leaf production usually brings about a decrease in leaf size (Cooper and Edwards 1961), while selection for early or late flowering often results in lowered fertility (Cooper 1961b). The present work has shown a broad negative correlation between protein and soluble carbohydrate content though the limits are sufficiently wide to allow selection of a large range of protein/carbohydrate combinations, and there is also some indication that in seedling material a high soluble carbohydrate level may be associated with a slower rate of leaf production. Even so, selection for high nutritive value within an already adapted variety is likely to present fewer problems than an attempt to introduce particular nutritive components from otherwise unadapted material.

It is obvious that much more operational information is required before a range of varieties of known nutritive value can be developed, but the important first step, the demonstration of genetic variation in these nutritive components, has now been taken.

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STUDIES ON THE SOLUBLE CARBOHYDRATE CONTENT OF GRASSES

D. I. H. Jones

In producing herbage of improved nutritive value an important consideration is that of breeding varieties of higher digestibility, but attention must also be given to the composition of the digested feed. It has been assumed in the past that a high crude protein content in herbage reflects a high nutritive value; recent evidence, however, has questioned the validity of this assumption. Thus Hickey (1960), in New Zealand, found high crude protein in improved pastures to be associated with a high rate of thermogenesis in dairy cattle leading to a lowered feed utilization. Work at the Welsh Plant Breeding Station (ap Griffith, 1960) has shown high crude protein to be associated with a high content of nitrate nitrogen which, from American evidence (Whitehead and Moxon, 1952), would be expected to have a deleterious effect on the health and performance of stock.

At the same time there is an increasing awareness of the significance of soluble carbohydrates in ruminant nutrition. There is evidence to indicate that the soluble carbohydrate content of herbage influences the relative proportions of volatile fatty acids produced in the rumen (*Rep. Grassl. Res. Inst.*, 1959-60, 79–80), which in turn may influence the yield and quality of the milk produced by the animal (*Rep. nat. Inst. Dairy, Reading*, 1960, p. 78). Further evidence shows that the utilization of protein (Chalmers and Ogilvie, 1960) and of non-protein nitrogen (Sapiro *et al.* 1949) are affected by the amount of soluble carbohydrate present in the rumen.

Of main interest to the plant breeder are the variations in soluble carbohydrate content *between* and *within* species. Work at this Station so far confirms the results of Waite and Boyd (1953), and others, in that considerable differences exist between species; differences of the same order may also exist within a single variety (Cooper, p. 145).

In order to assess the significance of these intra- and interspecific differences attention must be given to the influence of environment on soluble carbohydrate content. It is necessary to determine whether differences under one system of management are necessarily those found under another, and particularly

whether selections made at seedling stage under glasshouse conditions are valid under sward conditions in the field.

Environment undoubtedly plays an important, if not dominant, role in governing the soluble carbohydrate content of a plant. The effect of temperature, for example, is shown in Table 1, the data being derived from seedlings grown under different light and temperature regimes (Cooper, p. 16).

Table 1. Percentage water soluble carbohydrate content of ryegrass and cocksfoot varieties grown at different temperatures

	Temperature	
	10°C. day and night	*25°C. day/12°C. night*
Perennial ryegrass:		
Irish	8.5	2.8
S.23	13.5	3.0
New Zealand	8.6	2.8
Cocksfoot:		
Danish	8.6	2.2
S.341	8.0	2.2
S.143	7.0	2.8

Material from the same experiment grown in a heated glasshouse with and without low intensity supplementary light (50–150 ft. c.) shows that increased light can markedly increase soluble carbohydrate content (Table 2).

Table 2. Percentage soluble carbohydrate content of ryegrass and cocksfoot varieties with and without supplementary light. Harvested 20 *March* 1961

	Without supplementary light	*With supplementary light*
Perennial ryegrass:		
Irish	6.2	15.2
S.23	6.2	15.7
New Zealand	6.7	14.7
Cocksfoot:		
Danish	8.0	11.4
S.341	5.3	9.3
S.143	4.5	7.3

The importance of environment in governing soluble carbohydrate content under field conditions is indicated by a comparison of the changes taking place during the season in normal flowering ryegrasses with those in a non-flowering variety developed by Dr. J. P. Cooper. A series of single genotype swards from several varieties of ryegrass, including two non-flowering types, have been established by Mr. D. G. Miles. Weekly cuts were taken from these swards during May and June, 1960. Table 3 compares the soluble carbohydrate content of some of the swards during this period.

Table 3. Percentage soluble carbohydrate content of single genotype swards of ryegrass varieties during primary growth

Swards derived from perennial ryegrass	*Sampling dates* 1961					
	1 *May*	8 *May*	16 *May*	23 *May*	30 *May*	13 *June*
Kent (a)	12.9	20.1	25.0	32.8	32.8	12.0
Kent (b)	30.6	22.0	20.0	28.0	30.6	23.9
S.23	20.9	27.8	27.0	36.0	31.8	26.8
Irish	24.8	28.6	22.2	32.4	28.6	26.8
Non-flowering (a)	22.8	20.3	23.6	27.0	29.2	23.5
Non-flowering (b)	18.5	28.0	22.8	31.8	36.8	31.0

(a) and (b) represent swards derived from different plants.

It can be seen that the pattern of change in soluble carbohydrate content during the period under review is similar for both flowering and non-flowering swards although the latter remained completely vegetative. This suggests that environment, rather than stage of development, may be of first importance in determining soluble carbohydrate content during primary growth. The wide variation found within a variety is well illustrated by the different patterns of the two swards derived from Kent perennial ryegrass.

Management can also affect the soluble carbohydrate content of a sward by governing the proportion of leaf to stem. Waite and Boyd (1953) have shown soluble carbohydrate, particularly fructosan, to be higher in stem than in leaf. An experiment conducted in conjunction with Mr. Ieuan Davies (Grass Breeding), has shown the extent of differences between leaf and stem in S.24 perennial ryegrass at two stages of growth in the spring (Table 4).

In this experiment the stem contained about three times the amount of fructosan as the leaf at ear emergence. Preliminary results from the same experiment indicated that different leaves on the plant may differ considerably in soluble carbohydrate content at any particular stage of growth.

Table 4. Percentage soluble carbohydrates in leaf and stem of S.24 perennial ryegrass

	Plants with heads emerged		*Plants with heads not emerged*	
	Stem	*Leaf*	*Stem*	*Leaf*
Hexoses	5.72	2.99	5.83	3.64
Total sugars	9.09	13.99	11.31	9.10
Fructosan	21.70	8.80	20.14	7.27

Leaf = leaf blade; stem = stem, leaf sheath and head.

Glasshouse experiments (Vose, 1960; Alberda, 1960; Sprague and Sullivan, 1950) have shown that frequent defoliation and increasing nitrogen supply markedly decrease the soluble carbohydrate content of grasses. Under field conditions Waite (1957) has shown that increasing the amount of N.P.K. fertilizer when combined with frequent cutting results in a decreased soluble carbohydrate content. Parrish (1953) found that increasing the amount of nitrogen fertilizer resulted in a decrease in fructosan content of cocksfoot and perennial ryegrass. An experiment carried out by Mr. R. J. K. Walters (Grassland Agronomy) provided material for studying the effect of nitrogen fertilizers on the soluble carbohydrate content of pure grass swards during primary growth and under monthly cutting (Jones, *et al.*, 1961). Table 5 compares the soluble carbohydrate content of S.23 perennial ryegrass and S.143 cocksfoot during primary growth in the first harvest year. Nitrate of soda was applied at the rate of 4 cwt./acre one month before each sampling.

Table 5. The effect of nitrate of soda on the percentage soluble carbohydrate content of S.23 perennial ryegrass and S.143 cocksfoot during primary growth

	Sampling dates		
	5 *April*	17 *May*	13 *June*
S.23 perennial ryegrass			
No nitrogen fertilizer	17.5	24.3	22.3
Nitrate of soda	7.5	12.0	11.7
S.143 cocksfoot			
No nitrogen fertilizer	5.7	12.3	7.3
Nitrate of soda	2.7	6.1	3.7

At each sampling date the soluble carbohydrate content of the nitrogen fertilizer herbage was about half that of the unfertilized. Total nitrogen and nitrate nitrogen contents and dry matter production were considerably higher for the nitrogen treatment.

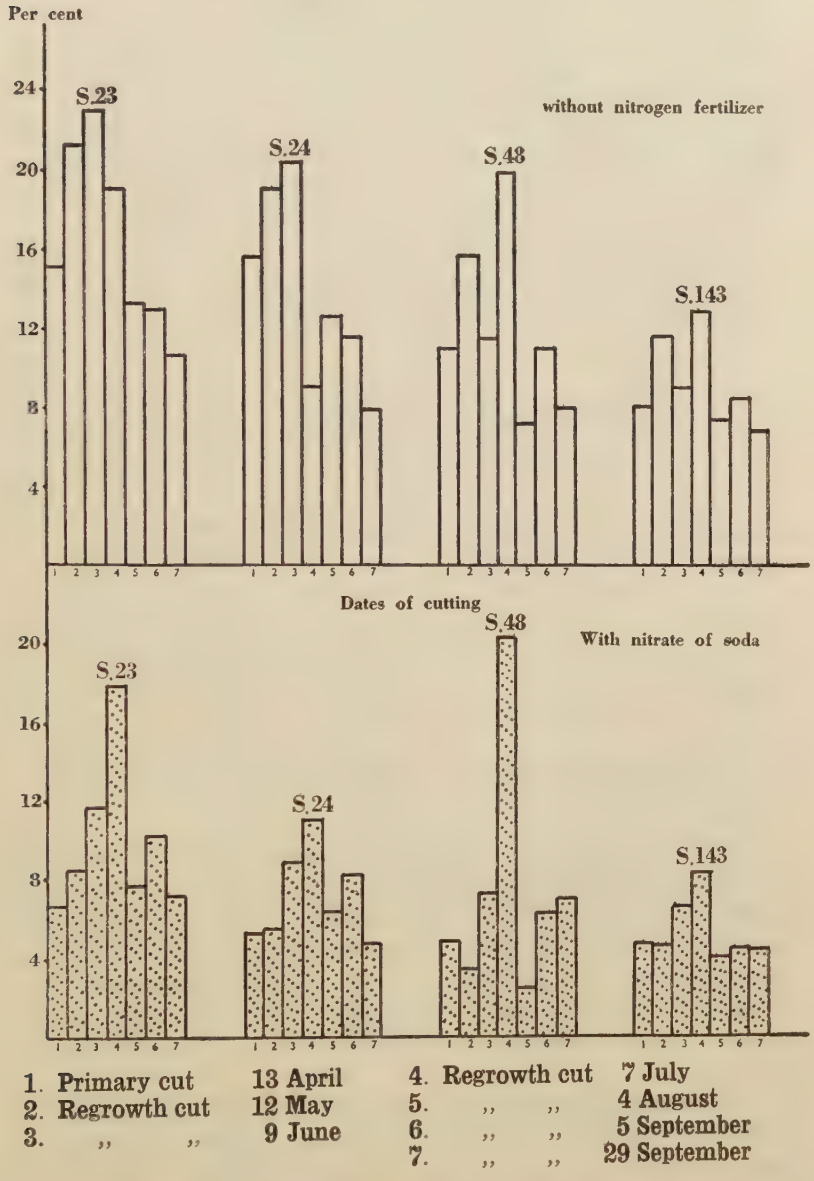

Fig. 1. The effect of nitrate of soda on the soluble carbohydrate content of monthly regrowth cuts from pure swards.

Fig. 1 shows the effect of the application of nitrate of soda on the soluble carbohydrate content of monthly regrowth cuts taken from swards of S.23 and S.24 perennial ryegrass, S.48 timothy and S.143 cocksfoot in the first harvest year. Nitrate of soda was applied at the rate of 4 cwt./acre one month before the first cut, and thereafter at each of the following monthly cuts. The nitrogen-treated swards again showed markedly lower soluble carbohydrate content, particularly in the spring and autumn cuts. Total nitrogen and nitrate nitrogen showed patterns which were inverse to those for soluble carbohydrate, that is highest in spring and autumn. Thus spring and autumn cuts show high total nitrogen and nitrate nitrogen contents but a low soluble carbohydrate content.

A study of the carbohydrate constituents included in the soluble fraction shows that the depression produced by nitrogen fertilizer is mainly due to a change in fructosan content (Table 6).

Table 6. Effect of nitrate of soda on total sugar and fructosan contents of S.23 perennial ryegrass and S.143 cocksfoot

Date		*S.23 ryegrass*		*S.143 cocksfoot*	
		Total sugars	*Fructosan*	*Total sugars*	*Fructosan*
13 April	—N	8.0	6.9	5.8	2.7
	+N	5.2	2.0	4.2	0.6
9 June	—N	6.5	12.7	4.8	5.3
	+N	6.0	8.8	4.4	1.6
4 August	—N	5.0	6.8	6.2	3.0
	+N	5.8	4.3	4.7	0.6
20 September	—N	6.5	2.0	5.1	0.7
	+N	5.5	1.3	4.3	0.4

This experiment also included a comparison of the effect of different forms of nitrogen fertilizer. The soluble carbohydrate content of swards which received nitrate of soda and urea was similar, despite a much higher dry matter yield from the nitrate of soda treatment. This indicates that the effect of nitrogen fertilizer on herbage soluble carbohydrates is not simply related to rate of growth. Species differences were maintained under all fertilizer treatments.

The second harvest year data from this experiment show a similar pattern to that in Fig. 1, the species differences and the depression due to nitrogen fertilizer being maintained. The nitrate

nitrogen pattern was also similar, except that values in the spring were considerably lower than in the first year.

The data from this experiment show that when high nitrate contents occur they are accompanied by low values for soluble carbohydrate. Sapiro *et al.*, (1949) and Barnett and Bowman (1957) have shown that the addition of glucose leads to a very rapid disappearance of nitrate during *in vitro* incubation with rumen liquor, suggesting that animals fed a diet high in soluble carbohydrate are less likely to show symptoms of nitrate poisoning. The implication of the present results would thus be that disorders in livestock due to nitrate are more likely to occur in the autumn, and in the cocksfoot rather than in the other grasses examined.

The depression in soluble carbohydrate resulting from the application of nitrogen fertilizer may be particularly significant in relation to the quality of autumn grass. Barnett and Reid (1961) point out that the autumn flush of protein-rich growth is usually produced artificially and that it may be doubtful whether the material contains enough readily-available carbohydrate to provide the necessary energy substrate for the rumen micro-organisms concerned in the utilization of nitrogen. These authors suggest that this may be responsible for the farmer's traditional grievance that his animals do not respond to autumn grazing as well as they do to spring grazing.

The incidence of hypomagnesaemia has also been related to the application of heavy dressings of nitrogen fertilizer while there is some evidence that the feeding of high carbohydrate diets reduces the incidence of the disorder (Hignett, 1961). The effect of nitrogen fertilizers on soluble carbohydrate may well, therefore, be of significance in this connection.

Further information is required on the value of soluble carbohydrate in the diet of the ruminant for the better evaluation of existing varieties and to indicate the qualities required in new varieties. It is important to remember, however, that the composition of the herbage finally available to the animal will be greatly affected by management.

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THE INFLUENCE OF THE ENVIRONMENT ON ANIMAL PRODUCTION IN WALES

RICHARD PHILLIPS*

The weather and climatic conditions are probably the most profound environmental factors affecting the welfare of wild and domestic animals. The abundance or scarcity of food as well as its quality over either a period of years or even shorter periods of drought and snow cover, depend to a large extent on circumstances beyond the control of the grower and husbandman.

In this island pronounced climatic differences occur within relatively small distances, particularly in Wales, a small country of 4½ million acres, where the whole range of elevation is barely 4,000 ft., where there are no large areas of uniform conditions of soil and vegetation, and where there are sharp differences in contours and in farming systems within relatively small distances.

The husbandry expert, the chemist, the botanist, the economist and the meteorologist, each in his own field, has studied these differences and illustrated them with maps and atlases. Perhaps it is the meteorologist with his records of rainfall, temperature, sunshine, humidity and phenological observations, who has provided the best picture of the relationship between climate and farming systems.

In broad outline, there are only two main farming systems in Wales, monoculture of sheep on the uplands and mixed stocking on the intermediate lands and the lowlands. Sheep can generally fend for themselves on the natural vegetation throughout the seasons of the year and it would be expected, therefore, that they could illustrate even delicate changes in the environment better than any other class of farm stock. Indeed, Seifert (1948) states "that sheep, compared with other animals are more sensitive indicators of climatic changes than the instruments of the meteorologist because they always register the whole." Consequently sheep kept in a locality are eventually moulded by, and are descriptive of, that locality. Cattle and horses (apart from mountain ponies) are wintered indoors and have to be fed on conserved fodder grown and gathered the previous summer. It is reasonable to assume, therefore, that the artificial conditions under which cattle are kept

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would reduce the influence of climatic conditions on their behaviour and reproduction. In this paper the data on the seasonality of reproduction in cattle provide evidence that climatic factors have a profound influence on winter conceptions, despite the artificial conditions under which the cattle are kept.

In this pastoral country grass is the main source of food for cattle and sheep, although it is usually supplemented by cereals and roots. New techniques as a result of research and mechanization have improved the yield as well as the quality of grass and fodder, and during the course of the years this has meant a heavier rate of stocking on the land. For example, during the 70's and 80's of the last century in Wales the total population respectively of cattle and sheep was about 700,000 and 2½ million. By the 1950's, however, the totals had increased to over a million cattle and 5 million sheep. The plant breeder has produced better and leafier grasses and clovers, and the agronomist has provided more suitable seeds mixtures, which with the more liberal use of fertilizers containing nitrogen has enabled the farmer to produce earlier and later growth of grass which eventually means a longer grazing season and a shorter indoor feeding period, as well as giving an increase in animal production.

Despite these advances in techniques it has not been possible to change the physical elements and, as shown by Davies (1948), late districts can not equal the earlier ones in yields of oats.

In the few coastal districts in Wales with more hours of direct sunshine and less cloud, fog and mist and higher average temperatures, grass grows practically through the winter and cattle are wintered out of doors with very little hay to supplement the grazing. It is in these same districts that early potatoes and other outdoor horticultural crops may be grown. In other districts it is customary to house cattle in winter.

Because of these climatic variations many farm practices have become traditional, especially those concerned with dates or day of the month. For example, to mention only one of many about cattle and sheep, when the Hill Ram Control Order became operative during the war, upland flockmasters were compelled to keep the rams away from the ewes until a particular fixed date so that the lambs would not be born too early the following spring, when weather would be hard and food in short supply. Flockmasters on the Eppynt insisted on the traditional date of 10 November, whereas those on Plynlimon were equally insistent on 25 October and those on the Preseli a fortnight earlier. Phenological data

examined by Bowen (unpublished data) showed how reliable tradition was, and how right the old practices had been. The Eppynt is colder in early April than the other places. Nichols (1933) described the stratification of the breeds of sheep in this country on the basis of average size in relation to the physical elements. On the other hand, Ashton (1930) maintained that the mature size of the native cattle over a wide stretch of Europe from Switzerland to Scotland was related to the lime content of the geological formations.

The opportunity to study this problem came with the introduction of compulsory measures for marketing fat stock and milk at the beginning of World War II. It was arranged to market all fat stock intended for slaughter through Collecting Centres of the Ministry of Food, to zone the collection of milk to factories, and to collect quarterly returns for the Ministry of Agriculture. The market towns became the collecting centres of fat stock for groups of surrounding parishes or assembling areas, and a local firm of auctioneers administered the scheme on behalf of the Ministry of Food. The four categories sold for slaughter were cattle, calves, sheep and pigs. Apart from the 'bobby' calves, which were sold on a per head basis, all fat stock was weighed and graded in accordance with the scheme. Eventually a massive volume of records relating to all animals passing through the centres became available for this operational research.

The area selected for study was Cardiganshire, Carmarthenshire and Pembrokeshire, sometimes described as the West Wales peninsula or the old Welsh province of Dyfed. Geographically it proved to be a convenient unit; geologically, apart from a fringe along the southern coastline, it was simple, consisting mostly of the Ordovician formation, whilst administratively it was splendid, because all the records from the 25 Collecting Centres which were distributed throughout the area were dealt with by one firm of auctioneers, Messrs. John Francis and Son, Carmarthen. These Centres varied in extent just as they differed in the volume of trade in fat stock.

Eventually a fairly complete picture of animal production in West Wales was prepared by Phillips *et al.*, (1949, 1950, 1951) on a monthly basis for a period of four years 1943-6. Later, similar surveys and studies were undertaken for the peninsulas of North Wales, South West England and the Solway in Scotland and these in general confirmed the findings from West Wales.

Two aspects only of the survey in West Wales are dealt with in this paper, the autumn calf sales, and the average dressed carcass weight of lambs.

West Wales

The three counties extend to nearly 1½m. acres of land, (1, 419, 743) of which approximately one-quarter was described in 1939 as rough grazing. It is a pastoral area ranging from sea level to its highest point on Plynlimon (2,468 ft.). In the past this was a well known stock-rearing area, exporting light and heavy horses, store cattle and dairy cows, store lambs and draft ewes. During this century dairy farming attracted more and more farmers, and after the establishment of the Milk Marketing Board in 1933, the change-over to dairying increased at a rapid rate, and today fully three-quarters of the farmers are in this industry. Further, during the past twenty years, the horse has practically disappeared and for that and other reasons the populations of cattle and sheep have increased. On the uplands the native Welsh mountain sheep remain the mainstay of the economy, whilst on the intermediate and lowland areas of mixed stocking, sheep of the lowland types are to be found in small flocks.

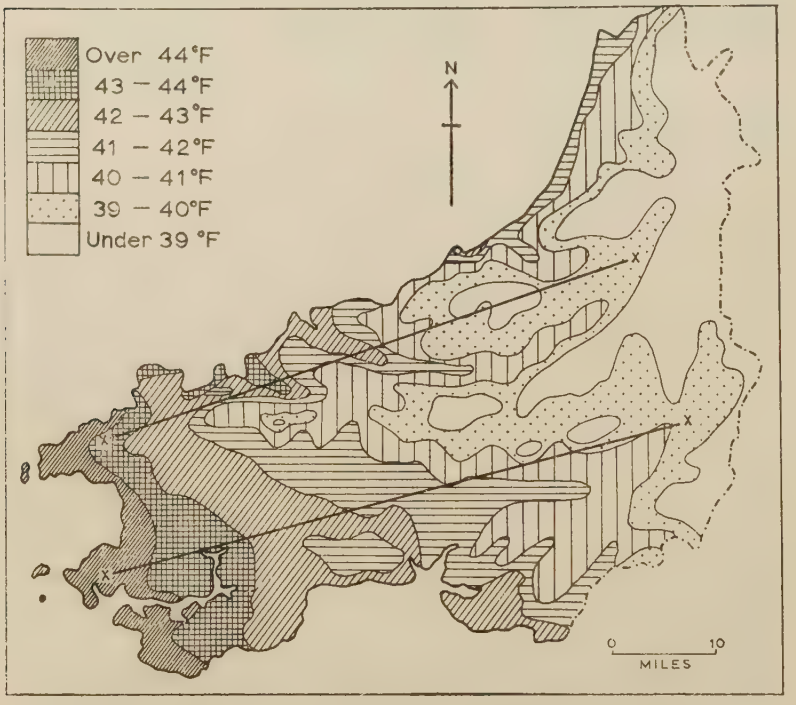

Fig 1. Average actual January Temperature 1906–35.
Compiled from averages published by the Meteorological Office.

These three counties, like the remainder of Wales and western Britain generally, consist of small farms; in 1939 there were 19,000 holdings above one acre and 11,600 above 20 acres, whilst three-quarters of the farms are below 50 acres. During the course of the years, rural depopulation and subsequent amalgamation of holdings have taken place, but the area is still a land of small farms.

The general climate is moist and temperate, although the higher ground is often snow covered in winter. Rainfall increases rapidly from the coast inland and it has been reported that the average annual rainfall in the coastal areas is a little below 40″ per annum, whereas it is quite double that on the western slopes of Plynlimon (Jones, Ll. Iorwerth, personal communication). In this study temperature differences were found to be of major importance, and the variations in the average actual January temperatures within the area are shown in Fig. 1, superimposed on which are the northern and southern transect lines (Table 1). The sunshine data are far from complete, but the few that are available indicate a fall in the average monthly hours from west to east and from the coast inland.

Autumn calf sales

During the war years dairying became a feature of farming policy, and farmers were encouraged and even urged to produce more milk for sale, particularly during the winter months. In order to do this they were advised to rear only dairy heifer calves for replacements and for the purpose of increasing the size of the herd. They were also to arrange for as high a proportion as possible of the cows and heifers to calve during the autumn. Male calves became a by-product of the industry and were disposed of as 'bobbies' or as veals through the Collecting Centres as soon as possible after birth. Accordingly, there was a rapid annual increase in the number of calves sold through the 25 Collecting Centres as shown by the following figures:

1940	37,886
1943	64,209
1946	83,719

The volume of calf trade per centre varied a great deal and the monthly percentages for each centre were used in comparisons,

the Carmarthen Centre being by far the most important. In the early years there was invariably a high peak of calf sales at each Centre during the spring months from March to May and only a modest rise in the autumn, following the very low sales in July. Towards the end of the period under study, taking the area as a whole, the spring peak had been reduced and the autumn peak considerably improved, showing that farmers had succeeded to some extent in arranging for autumn calvings as a result of January services and conceptions. The graphs for each of the three counties were prepared separately, and they showed that Pembrokeshire had succeeded to a far greater extent than the other two in arranging for autumn calvings.

When the histograms for the average percentage monthly calf sales were prepared for each of the 25 Collecting Centres for the four year period (1943-6) as illustrated in Figure 2, the picture took definite shape and form.

Fig. 2. Monthly distribution of calf sales at markets in west Wales based on the average for the 4-year period 1943–6.

The histograms for the Centres in the western end of the peninsula (Pembrokeshire) illustrate a high spring and autumn peak in calf sales, in contrast to those on the eastern parts where the spring peak is very high and where there is no autumn peak. In the intermediate centres, they show a gradual decline in the height of the

autumn peak from west to east. These changes must have been effected by circumstances beyond the control of the farmers, and the success in arranging for autumn calvings determined by factors other than those of husbandry. It had already been proved, by reference to the milk sales and the quarterly returns of the Ministry, that the monthly distribution of calving in those years was accurately reflected in the monthly distribution of calf sales. Autumn calvings depend upon January conceptions and therefore on the development of oestrum in cattle in that month. January is invariably a cold, cloudy month during which oestrum is slow to develop. The graphs show that the ability to succeed declined from west to east.

The similarity of the general picture of autumn calf sales (Fig. 2) and the January isotherms (Fig. 1) is remarkable. The comparison of the January isophenes with the peaks of autumn calf sales, as in Fig. 3, shows a similarity which is striking and complete. The percentage rates of autumn calving and the transects shown in Fig. 3 support this view, and in later years the A.I. records also show peaks in demands for semen during January and June.

Average carcass weight of lambs (1943-6)

As a result of the rapid development of dairying, together with other reasons of policy, the sheep population in the three counties fell from 844,000 in 1939 to 622,000 in 1944. Compared with the other two counties, Pembrokeshire with its lower proportion of uplands and therefore of upland sheep, showed a more rapid fall in numbers passing through the Collecting Centres which was due to the reduction in lowland flocks. During the war years there was a decline in the number of sheep (lambs, rams, ewes, wethers) passing through the Collecting Centres from 288,000 in 1940, to 197,400 in 1943 and to 168,000 in 1945. Although there was a slight increase in 1946 when the total was 185,500 it fell again after the winter blizzards of 1947 to 124,227, the lowest on record. During the six years 1940-6, the total number of all the categories of sheep sold for slaughter amounted to some $1\frac{1}{4}$ million and that from an area of 1.4 million acres, or about one sheep/acre, in six years.

Approximately 85% of all sheep deliveries consisted of fat lambs, and during the four years under review (1943-6) nearly 600,000 passed through the 25 Collecting Centres. The numbers

passing through each Centre varied a great deal, from 144,000 in the large Aberystwyth area to about 8,000 in the small areas of Narberth and Crymmych. The examination of the records showed a wide range in the average carcass weight (E.D.W.) from 28 lb. in Tregaron to 52.5 lb. in Pembroke although all the average annual figures were remarkably constant for each centre.

The price policy during the war encouraged farmers to produce the heaviest possible weights of fat lambs and, therefore, the average E.D.W./Centre is an indication of the capacity of the collecting areas to produce fat lambs—the joint effort of all the producers in an area. It is quite immaterial whether the comparisons are made on the 4 yr. averages, the average E.D.W. of the summer suckling lambs, or on the average E.D.W. of the autumn product. The figures might be slightly different, but the trend, or cline, from west to east remains the same.

This is shown in two transects of the peninsula from west to east (Fig. 1). Along the northern line there are a successive series of Centres from Croesgoch (near St. David's) in the west, to Tregaron in the east. The southern transect runs from Pembroke in the west to Llandovery in the east. It is very remarkable that there should be a parallel fall in E.D.W. from west to east along these two lines, and it can only be accounted for by environmental factors beyond the control of the producers, i.e., the physical elements.

Table 1. Transects of average annual E.D.W. (lb.) of lambs 1943-6. *(See also Fig. 1.)*

Northern	*Croes-goch*	*Mathry*	*Crym-mych*	*Newcastle Emlyn*	*Llan-dyssul*	*Llany-bythe*	*Lam-peter*	*Tre-garon*
Lambs	46.2	48.8	39.4	42.8	39.4	36.1	32.9	28.3
Summer suckling lambs	43.3	46.3	40.3	40.8	39.2	39.1	36.1	32.9

Southern	*Pem-broke*	*Kil-getty*	*Whit-land*	*St. Clears*	*Carmar-then*	*Llan-deilo*	*Llan-gadock*	*Llan-dovery*
Lambs	52.6	47.1	43.8	44.8	41.8	37.2	34.4	33.0
Summer suckling lambs	46.1	44.4	44.3	42.6	41.2	40.6	38.5	37.2

In the above picture there are a few misfits. In the northern transect the figures for Newcastle Emlyn are slightly higher than those for Crymmych, but the former is a centre in the Teify valley, mainly a lowland collecting area, whereas Crymmych is at a higher elevation on the slopes of the Preseli, with a proportion of lambs of mountain origin. It is very surprising that the averages for

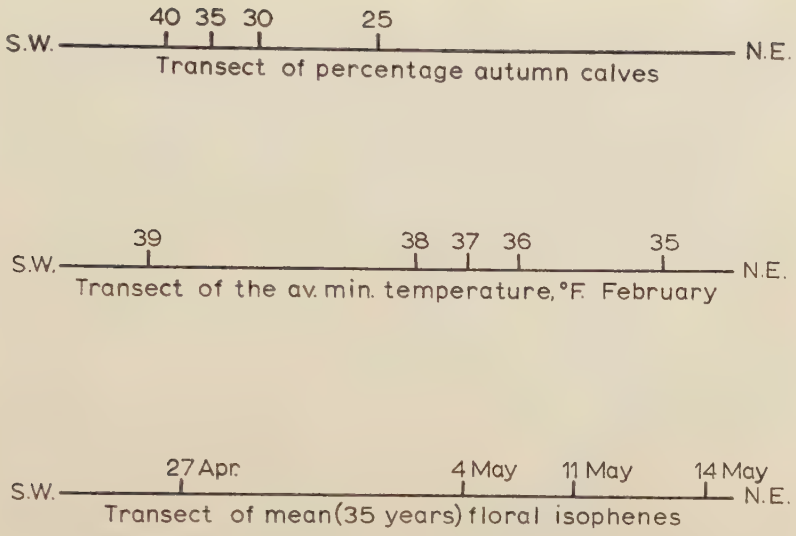

Fig 3. These transects are from S.W. (St. Ann's Head) to N.E. (Gwernyfed Park), a distance of approximately 80 miles (From Book of Normals of Meteorological Elements.)

Crymmych are so good. Another feature of the two transects is that the *average* E.D.W. is higher than that of the *summer suckling lambs* in the west; they are about equal in the intermediate centres, and in reverse in the eastern centres. This of course is explicable on the basis of systems of sheep husbandry, for the average E.D.W. is dominated by the large number of lambs of mountain origin which come on to the market in the autumn, whereas the summer lamb is the direct product of cultivated pastures.

The gradual cline from west to east follows exactly the pattern of the floral isophenes in Fig 3. It is to be concluded, therefore, that the influence must be due to the changes in the environmental condition, largely climatic, which are beyond the control of the husbandman.

Studies of a similar nature in the other western peninsulas of Britain support this view, and to a very large extent it is also confirmed by the average live weight and grading of beef cattle.

Sunshine, temperature and cloud cover are of the utmost importance in the agriculture of Wales, and in districts where they are unfavourable the farmers are liable to be unduly penalised.

This is most generally appreciated in connection with the hay and corn harvests and the consequent effects on animal health and

production. To some extent modern techniques have overcome harvesting hazards through the adoption of (a) alternative methods of conservation (dried grass and silage); (b) mechanization and (c) repeated teddings to produce 48-hour hay. Despite these advances homegrown winter fodder is still inferior to summer grass.

Climatic influences are more subtle than merely the direct effects of too much rain and too little sun on grass and fodder. In former days attempts to understand and overcome these difficulties came through amelioration (a composite term which included drainage, reclamation, cultivation, burning and manuring) and improvements derived from the use of better seeds, the mechanical preparation of animal food, and the provision of shelter belts, hedges and outbuildings. In due course, with the better understanding of the principles of nutrition, there was a more balanced feeding which considerably improved the lot of livestock on the farm and the new systems of farming reduced the farmers' economic stresses. Veterinary science also made an important contribution to animal welfare.

In this paper the influences of climatic conditions are illustrated in time and space on reproduction in cattle and growth in lambs, and it is clear that despite scientific advances, the husbandman is still unable to overcome the disadvantages of unfavourable physical condition of land and climate. The Welsh Plant Breeding Station in its early days obtained startling results from determinations of protein content, ratio of stem/leaf and from other agronomic studies. These advances in due course were passed on to the husbandman to his great advantage.

The physiologist, biochemist and geneticist are now exploring the effects of the intensity of solar radiation on the complex processes of photosynthesis. The Welsh Plant Breeding Station has already made advances in this field, more particularly in connection with the seasonal variations in nitrate content and sugar/fibre ratios of herbage plants. The results indicate that grass growing during the cloudy, shortening days of autumn is very much inferior in the above components to grass growing in the spring, even the same varieties grown under identical conditions. Furthermore, these differences are accentuated when comparisons are made between the sunny and the cloudy areas. The geneticist is taking full advantage of this information. The differences illustrated in this paper may perhaps be related to variations within the plant, and some ailments and disorders such as hypomagnesaemia and acetonaemia may be due to the same or similar complexities. It is now possible to fore-

see the direction in which the plant breeder of the future will be guided by the results of these fundamental researches. Consequently, the agronomist will be able to prescribe seeds mixtures, not so much on the basis of soil, leafiness, earliness and persistency, but in relation to their suitability for separate zones of climatic conditions. Maybe, then, some of the prevailing ailments will disappear. Accordingly, the farmer of the future needs to become an expert and a specialist in his own particular field of husbandry and 'field' here is of geographic significance.

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ABERYSTWYTH S.321 PERENNIAL RYEGRASS
(Ba 6293)

Origin and breeding

This variety originated from seeds of individual inflorescences collected from wild habitats in south-west Cornwall, and is bred for high resistance to autumn and winter burn.

Botanical characteristics

Intermediate in date of heading, being about 15 days later than S.24. Leafy, high tillering. The spaced plants have a dense basal cushion-like growth characteristic of a typical grazing variety.

Agronomic behaviour

Aberystwyth S.321 perennial ryegrass is a leafy pasture variety with better spring growth properties than S.23. In trials involving a number of varieties in swards subjected to a range of managements S.321 outyielded S.23 by a significant margin in spring under each system of management imposed. This superiority, which is most marked in a late season, is true spring growth, and not the result of a carry-over of late autumn growth into the spring. The production of S.321 in June and July is appreciably better than S.24, but not as good as S.23. S.321 produces fewer heads in the aftermath than S.24; its production compares favourably with S.23 in the autumn.

S.321 is less affected by winter burn than most other ryegrass varieties, particularly in the first winter after seeding. The growth during December to February is superior to S.23.

This variety combines some of the best characteristics of S.23 and S.24, and should be very useful for pasture purposes where winter greenness and good spring production are desired.

Seed production

S.321 has large seeds which germinate and establish well, and in comparative seed production trials it gave significantly more seed than S.24.

ABERYSTWYTH S.341 COCKSFOOT
(Bc 4075)

Origin and breeding

This variety originated from seeds collected in south-west France during 1948, and is bred specifically for early spring fodder.

Botanical characteristics

Early flowering, comes into head about 14 days earlier than S.37. Leafy, high tillering, erect in growth habit.

Agronomic behaviour

Aberystwyth S.341 is an exceptionally early-growing variety of cocksfoot which can provide excellent grazing in March and April, or alternatively, heavy hay crops in late May.

S.341 begins active growth in spring about three weeks earlier than Danish or S.37, an advantage which increases in successive harvest years. In simple mixture swards S.341 has consistently given increases in yield of 40% to 60% over S.37 and Danish early in April. In mixed swards the early growth potential is not reflected in higher total yields until the second harvest year. If full use is made of the early growth potential of S.341 and it is grazed in early spring, its subsequent performance during the summer will be inferior to that of later varieties. If, however, such early growth is not exploited and the crop is allowed to continue uninterrupted growth to the hay stage, a very much earlier and equally heavy crop can be obtained.

Aftermath growth is good following hay crops put-up early or late. It makes appreciably more growth during the milder spells in winter than Danish, but is more liable to winter burn than S.37.

S.341 cocksfoot is relatively slower to establish than S.37 and Danish. Subsequently, and irrespective of the intensity of defoliation, it is more aggressive than either.

Early spring production is favoured by regular rest periods in the previous autumn; the herbage should not be allowed to enter the winter in a very lush condition.

Seed production

The seeds of S.341 are relatively large, and seed yields compare favourably with S.37 cocksfoot.

ABERYSTWYTH S.352 TIMOTHY
(Bd 2308)

Origin and breeding

This variety originated from material introduced from a number of north-western European countries and is bred as a more typical hay type than S.51.

Botanical characteristics

Comes into head 14 days earlier than S.48; high tillering, erect, with well leafed culms; resistant to rust.

Agronomic behaviour

Aberystwyth S.352 timothy is very well suited to the production of heavy, leafy crops for conservation as silage or hay in May or June. It establishes well and gives good production in the seeding year. In early spring and until mid-April, S.352 timothy is less productive than S.51, but as the season advances, and by mid-May, it yields more than S.51. Hay cuts in early June show S.352 to considerable advantage especially in simple mixtures with red clover where it outyields S.51 by over 20%. Later, during September and October, S.51 is more productive.

S.352 is less aggressive than S.51 towards companion red clover which is thus able to make its maximum contribution to production in the sward. It can, however, be at a disadvantage in early summer in comparison with S.51 if it is grazed hard after mid-April.

S.352 is recommended for use in simple mixtures; S.51 is a more valuable variety for use in general-purpose mixtures especially with highly competitive varieties of perennial ryegrass.

Seed production

The seed sample has a bold appearance and seed yields have proved highly satisfactory.

MAELOR (S.236)

General information

A spring oat variety developed from a cross made in 1937 between the Station bred variety S.175 and Eagle. Registered in 1961, first release of Foundation Seed made in 1962.

Maelor is a special-purpose variety produced for localities where a good bulk of straw is required as well as grain of good milling quality. On account of its high total forage production Maelor is also ideally suited for use as a silage oat. Its straw is 6″ to 8″ taller than either Sun II or Blenda, but nevertheless it is superior to both in standing ability, and it is also less susceptible to mildew attack. In date of maturing it is similar to Blenda. The grain of Maelor is white to creamy-white, of good size and because of its exceptionally thin husk it is of very good milling quality.

Placed on the N.I.A.B. list of Recommended Varieties of Spring Oats in 1962 under category (S).

Descriptive features

Young plant

Habit of seedling growth erect; low tillering. Leaf margins and leaf sheaths usually free from hairs.

Mature plant

Flowering culm: Long, fairly stout culms with a much extended internode subtending the panicle. Nodes glabrous.

Panicle: Equilateral, medium to large open panicle with the main branches at lower nodes slightly ascending before reaching full maturity.

Spikelets: Pendulous at flowering, normally 2-grained, terminal spikelets occasionally 3-grained.

Grain: White to creamy-white, well shaped and of good size. Lateral tufts of hairs on base of primary grain. Rachilla glabrous, medium long and usually lightly or distinctly grooved. Awns rare, usually weak when present, percentage of husk low.

Kernel content	76 to 79%
Weight per 1000 grains	36 to 40 gm.

PADARN (S.237)

A high-yielding winter oat variety developed from a cross made in 1948 between Powys and a winter-hardy, mildew-resistant selection derived from S.147 × 01747/10/7. Registered and introduced into commerce in 1962.

In official N.I.A.B. trials over the years 1958-1961, under Station No. 5370 Cn 2/2/41 Padarn outyielded Powys by 10%, and S.147 by 14%. Its grain is white, medium sized and of good quality. This new variety also manifests a high degree of winter hardiness and is the earliest of all the recommended winter varieties to reach maturity, being on average a few days earlier in ripening than S.147. The straw of Padarn is some 6″ to 8″ shorter than S.147, and is more resistant to lodging than either S.147 or Penrhyn. With these improvements in field characters Padarn is intended as a potential replacement for S.147 and Penrhyn. In the field Padarn has shown excellent resistance to mildew and is of special value in areas where both winter and spring oats are grown, since the early spread of the disease to spring sown oats will be much reduced if the autumn sown crop can prevent the overwintering and build-up of the mildew inoculum during autumn, winter and spring.

Placed on the N.I.A.B. list of Recommended Varieties of Winter Oats in 1962.

Descriptive features

Young plant

Habit of growth prostrate to semi-prostrate, margins of leaf blades hairy for half to three-quarters of their length, leaf sheath hairs short and fairly dense.

Mature plant

Flowering culm: Medium length, fairly stiff straw, being on average about 6″ to 8″ shorter than S.147; nodes glabrous.

Panicle: Equilateral, medium to fairly large in size and spreading, drooping slightly at apex; main branches at lower nodes ascending slightly.

Spikelets: Pendulous, usually 2-grained. Glumes well developed and at flowering light greyish-green. Uppermost spikelet bases and pedicels frequently with a purplish tinge.

Grain: White to creamy-white with the inner palea sometimes tinged light brown; slightly slender medium sized grain with a thin husk. Base of grain usually glabrous; rachilla glabrous, long and slender, frequently lightly grooved. Awns absent or very rare.

Kernel content	74 to 77%
Weight per 1000 grains	35 to 39 gm.

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